# CRUX PROJECT

## OFFSHORE PROJECT PROPOSAL

**June 2020**

# Crux Offshore Project Proposal

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# EXECUTIVE SUMMARY

## Introduction

### Project

Shell Australia Pty Ltd (Shell), together with Joint Venture Participants Seven Group Holdings (SGH) Energy and Osaka Gas, is progressing planning for the prospective development of the Crux gas field, located approximately 160 km north-east of the Prelude field in the northern Browse Basin, offshore the Kimberley coast, Western Australia (WA) (**Figure ES-1**).

The Crux field is located in Commonwealth marine waters in the northern Browse Basin, 190 km offshore north-west Australia and 620 km north-north-east of Broome.

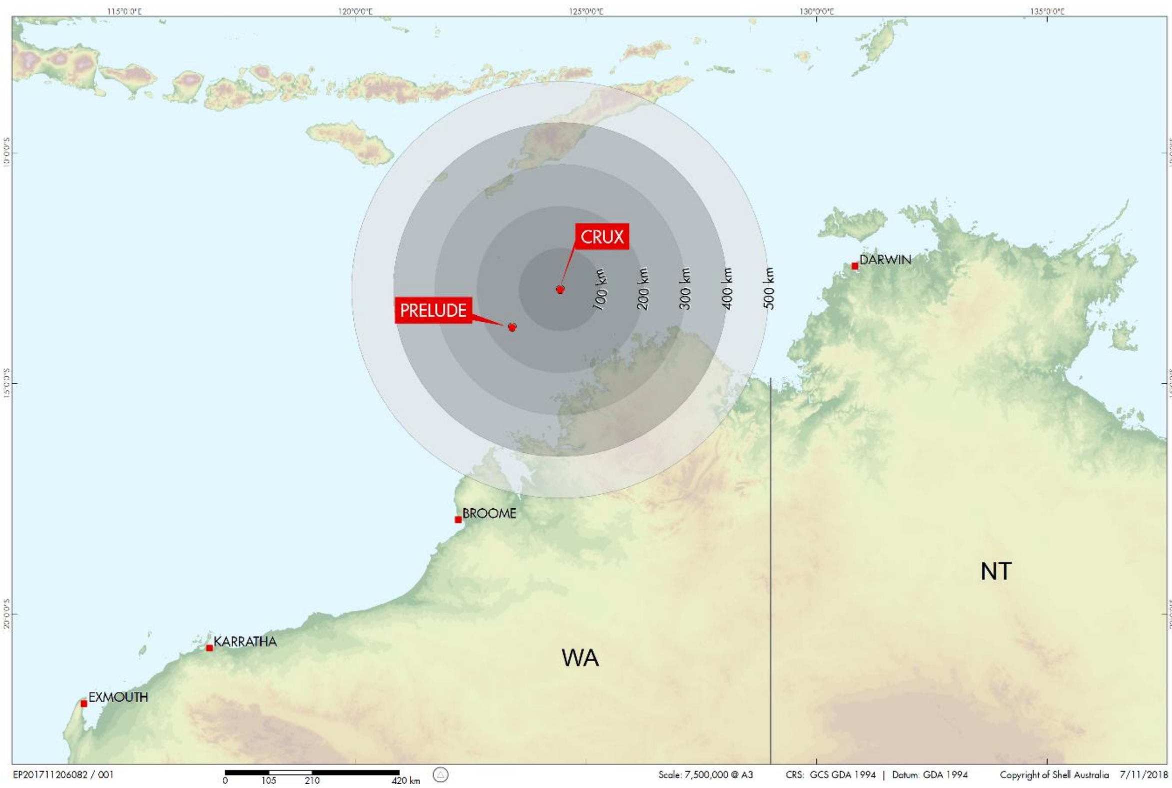



Figure ES-1: Location of the Crux Project

The Crux project has been identified as the primary source of backfill gas supply to the Prelude Floating Liquefied Natural Gas (FLNG) facility. The proposed Crux project consists of a Not Normally Manned (NNM) platform in approximately 165 m water depth; with five production wells, minimal processing and utility systems, tied back to the existing Prelude FLNG facility via a 165 km export pipeline. Crux will be operated remotely from the Prelude FLNG facility.

The current Crux project concept is shown in **Figure ES-2**. Front-End Engineering and Design (FEED) for the project commenced in 2019 with the Financial Investment Decision (FID) currently scheduled to occur in 2020. The project is anticipated to have a 20-year design life. However, subject to the future investment decisions, the project may extend.

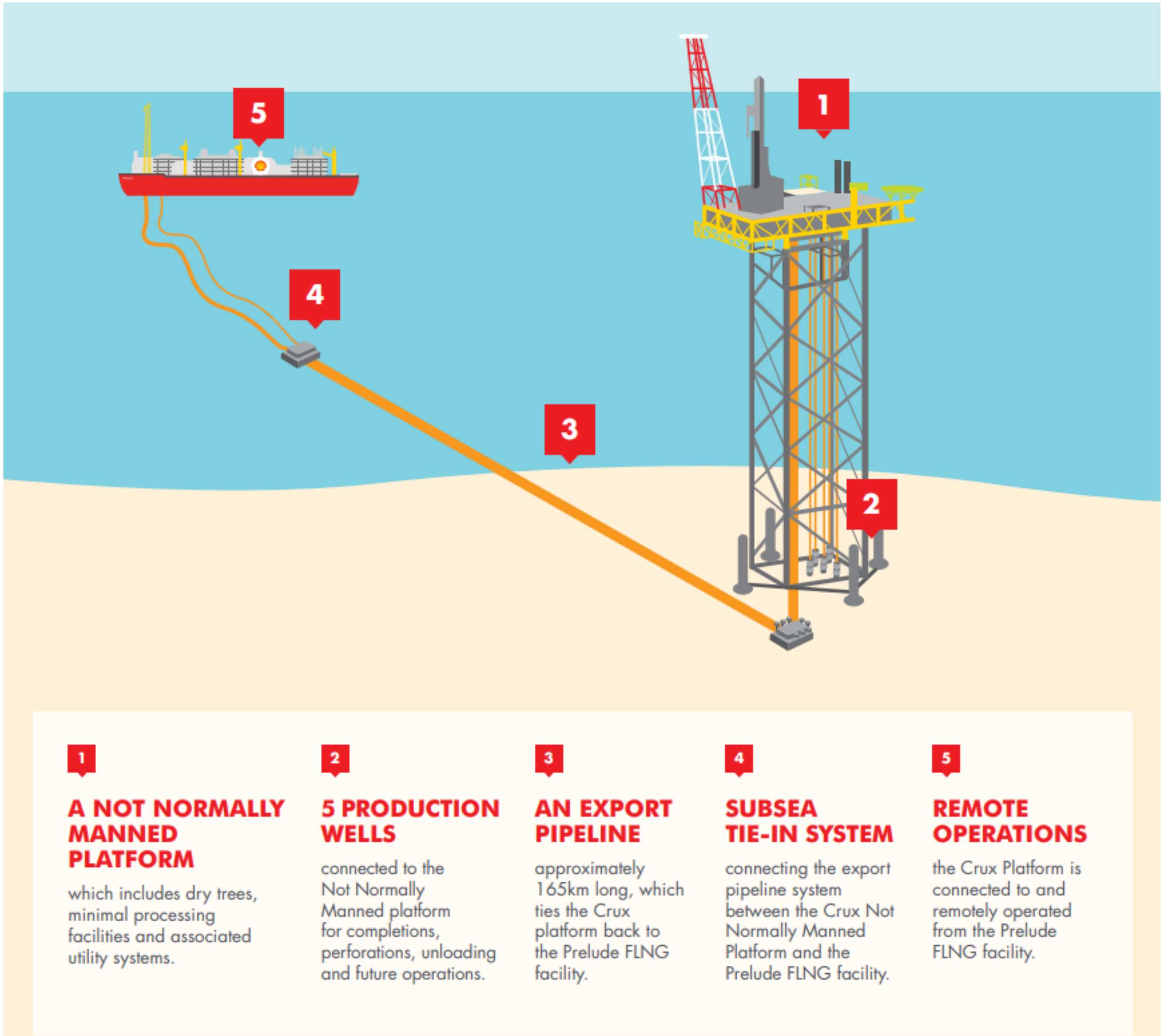



Figure ES-2: Crux Project Concept

## Proponent

The project proponent for the Crux project is Shell Australia Pty Ltd (Shell). The Shell Group of companies is the largest equity Liquefied Natural Gas (LNG) producer among international energy companies and has the most diverse LNG supply portfolio in the world. The Shell Group has been in Australia since 1901 and has continued to evolve to meet the changing needs of the Australian and international markets. Today, Shell is focused on the exploration, development and production of LNG, domestic gas and associated products such as liquified petroleum gas and condensate. Shell is a major investor in key Australian LNG projects, including the Shell-operated Prelude FLNG facility.

Shell's Joint Venture Participants for the Crux project are SGH Energy and Osaka Gas. SGH Energy is an Australian oil and gas company with a portfolio of high quality assets and a resources base in the offshore Gippsland Basin in Victoria, and in the Browse Basin in northern WA. Osaka Gas has over 110 years of experience in the energy sector and has grown into a diversified energy company, across the entire natural gas value chain. The

Crux Joint Venture Participants bring collective expertise and support for the sustainable commercialisation of the gas fields, in support of backfill to the Prelude FLNG facility.

### Offshore Project Proposal Process

Shell determined that the Crux project constitutes an offshore project that requires approval under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006*. Subsequently, Shell has developed this Offshore Project Proposal (OPP) to meet this requirement.

The impact assessment of the proposed project presented in this OPP has been aligned to meet the requirements of an OPP regulated under the Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations) and administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

An assessment of the proposed Crux project has been progressed, in accordance with the Shell Health, Security, Safety, Environment and Social Performance (HSSE & SP) Control Framework, to *'identify and assess the potential environmental, social and health impacts of a project, and to implement measures so that negative impacts are minimised, and positive impacts are optimised.'*

The purpose of the OPP is to describe:

- the project area, the proposed activities and its expected timeframe
- the environmental management framework for the proposal, including legislation and other requirements
- the existing natural, social and economic environments of the local and regional setting, including issues or sensitivities particular to the proposal
- the possible impacts and risks to the environment from both planned (normal) and unplanned (emergency) operations
- Shell's HSSE & SP Commitment and Policy and the environmental performance objectives that derive from the Policy, and
- a framework for the forward environmental management and performance, including definition of key management controls and Environmental Performance Outcomes (EPOs), from which environmental performance will be measured and monitored throughout the life of the project.

The OPP is designed as an early stage, whole-of-project assessment. Subject to NOPSEMA's acceptance of the OPP, it will form the basis of future activity-specific Environment Plans (EPs) that will be submitted to NOPSEMA for acceptance as part of subsequent staged development and permitting.

## Policy, Legal and Administrative Framework

As the Crux project is located in Commonwealth waters, the key legislation of relevance to the Crux project include:

- *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) – the OPGGS Act, and subsidiary Offshore Petroleum and OPGGS (E) Regulations, ensures that all offshore petroleum and greenhouse gas storage activities are undertaken in a manner where impacts and risks on the environment are of an acceptable level and reduced to as low as reasonably practicable (ALARP). This includes risks to Matters of

National Environmental Significance (MNES) protected under Part 3 of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The OPGGS Act requires that all activities are consistent with the principles of ecologically sustainable development (ESD), as defined in the EPBC Act.

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – The EPBC Act and supporting regulations provides for the protection of the environment and conservation of biodiversity in Australia (including Australian waters) by the Commonwealth Government. Amendments to the OPGGS Act and OPGGS (E) Regulations in February 2014, undertaken as part of the Commonwealth streamlining environmental approvals process, require MNES to be addressed in assessments of offshore petroleum development approvals. Therefore, the OPP process under the OPGGS (E) Regulations supersedes the Commonwealth referral process under the EPBC Act and replaces the requirement to prepare environmental approvals for submission to the Department of the Environment and Energy (DoEE) for petroleum development activities in Commonwealth waters. As such, this OPP addresses the EPBC Act requirements for the Crux project, including those outlined in the EPBC Act Management Plans, Recovery Plans and Conservation Advices.

The administration of petroleum activities in Commonwealth waters is subject to a number of requirements administered by the National Offshore Petroleum Titles Administrator (NOPTA) and NOPSEMA. These requirements include:

- Environment Plans – all petroleum activities within the scope of this OPP must be undertaken in accordance with an EP accepted by NOPSEMA. EPs must describe the activity, the receiving environment, and provide a detailed evaluation of environmental impacts and risks associated with the activity. The EP is also required to outline appropriate EPOs, performance standards and measurement criteria for determining whether the outcomes and standards are met. In addition, an implementation strategy is provided to demonstrate how the impacts and risks will be managed to ALARP and acceptable levels, how performance outcomes and standards are met, and detail the arrangements in place to respond to and monitor oil pollution emergencies. A series of EPs will be developed by Shell for specific activities throughout the project life cycle.
- Safety Cases – NOPSEMA requires an accepted Safety Case be in place for the Crux platform and pipeline. The Safety Case identifies the hazards and risks for a facility, describes the measures in place to control these hazards and risks, and outlines the safety management systems that will be applied.
- Well Operations Management Plans (WOMPs) – all wells for the Crux project will be drilled, operated and abandoned in accordance with the requirements of an accepted WOMP.

## Shell Health, Security, Safety, Environment and Social Performance Management Framework

The Shell HSSE & SP applies across the Shell Group and is designed to protect people and the environment. The policy illustrates the commitment made by the senior management and all staff of Shell to achieve not only compliance with environmental standards set by the Australian Government and the Company, but also to seek continual improvements in performance.

Key features of the policy are:

- systematic approach to HSSE & SP management designed to ensure compliance with the law and to achieve continuous performance improvement
- targets for improvement and measurement, appraisal and performance reporting
- requirement for contractors to manage HSSE and SP in line with this policy, and
- effective engagement with neighbours and impacted communities.

All Shell's operations are conducted in accordance with Shell's HSSE & SP Control Framework, a comprehensive corporate management framework. This Framework defines a set of mandatory requirements that define minimum HSSE & SP principles and expectations.

## Stakeholder Consultation

Stakeholder engagement and consultation is an integral part of Shell's social performance, impact assessment and project development process, helping to both inform business decisions and identify issues that require action.

Shell is committed to:

- inform stakeholders of the proposed Crux project
- maximise the level of accurate and accessible information about the project
- provide stakeholders with the opportunity to engage in meaningful dialogue
- listen to feedback from stakeholders and respond to them honestly and responsibly
- use stakeholder feedback to inform and improve business decisions, and
- deliver a net benefit to local communities.

A Stakeholder Engagement Plan specific to the Crux project has been developed and includes a stakeholder matrix, an engagement strategy and a feedback mechanism.

As part of Shell's commitment to early engagement, a Crux project website has been established and initial factsheets published, providing an overview of the project and the OPP process. The Crux project website is located at: https://www.shell.com.au/about-us/projects-and-locations/the-crux-project.html

An initial industry briefing has been held, and Shell has commenced targeted engagement with a range of relevant stakeholders, including Government agencies, commercial fishing associations and other interested stakeholders, to discuss the project's status and facilitate the opportunity for feedback.

A core element of the OPP process is to facilitate a public comment period. The OPP was published on NOPSEMA's website and made available on Shell's website. For the Crux project, the OPP was released for a six week public comment period from 4 February 2019 to 18 March 2019.

Upon acceptance of the OPP, Shell will uphold its commitments to ensuring relevant persons continue to be consulted throughout the development of the Crux project. These consultations will be planned, tracked and recorded as part of the Crux Stakeholder Engagement Plan.

# Description of the Project and Alternatives Analysis

## Key Components

The Crux project has been identified as the primary source of backfill gas supply to the Prelude FLNG facility. The current project concept is shown in **Figure ES-2** and comprises:

- an NNM platform, which includes dry trees, processing facilities and associated utility systems
- five production wells with subsea wellhead system tied back through rigid concentric tubulars to the NNM platform and completed with dry trees
- a 26-inch export pipeline, approximately 165 km long, which ties the platform back to the Prelude FLNG facility, and
- subsea integration system connecting the export pipeline system with Crux platform and the Prelude FLNG facility, comprising risers, subsea isolation facilities and associated control systems.

There is also a potential for future subsea developments that will provide hydrocarbons to the Crux platform. These developments are expected to comprise subsea production wells, completed with subsea trees, and associated subsea tie-back to the platform (e.g. flowlines, risers and manifolds).

## Project Area

The Crux in-field development area and export pipeline corridor define the geographic extent of the project area that is applicable for planned activities, which are considered and risk assessed in this OPP. For the purposes of this OPP, the extent of the in-field development area (approximately 282,000 ha) and export pipeline corridor (approximately 32,000 ha) (collectively referred to as the ‘project area’) is considered to comprise the area outlined in **Figure ES-3** and **Figure ES-4**, respectively.

The in-field development area incorporates the development of the Crux field and associated fields that may be developed as future staged developments. The outer radius of potential backfills from the proposed Crux platform location will be 30 km from the current proposed platform location, excluding a 1 km buffer from around shoals within this area in order to avoid impacts to these features from potential future tie-backs. The preferred Crux platform location shown in **Figure ES-3** will be located within an approximate 1 km radius of this location.

The in-field development area also encompasses the marine environment that may be affected by planned discharges, as identified from modelling which is presented in the OPP.

The export pipeline route connecting the Crux platform to the Prelude FLNG facility includes a 1 km buffer either side of the proposed route where minor deviations in the final pipeline route may occur, as shown in **Figure ES-4**. A slightly larger buffer (approximately 2 km) has been allowed at the Prelude end of the pipeline to allow for tie-in to the most appropriate quadrant of the FLNG turret.

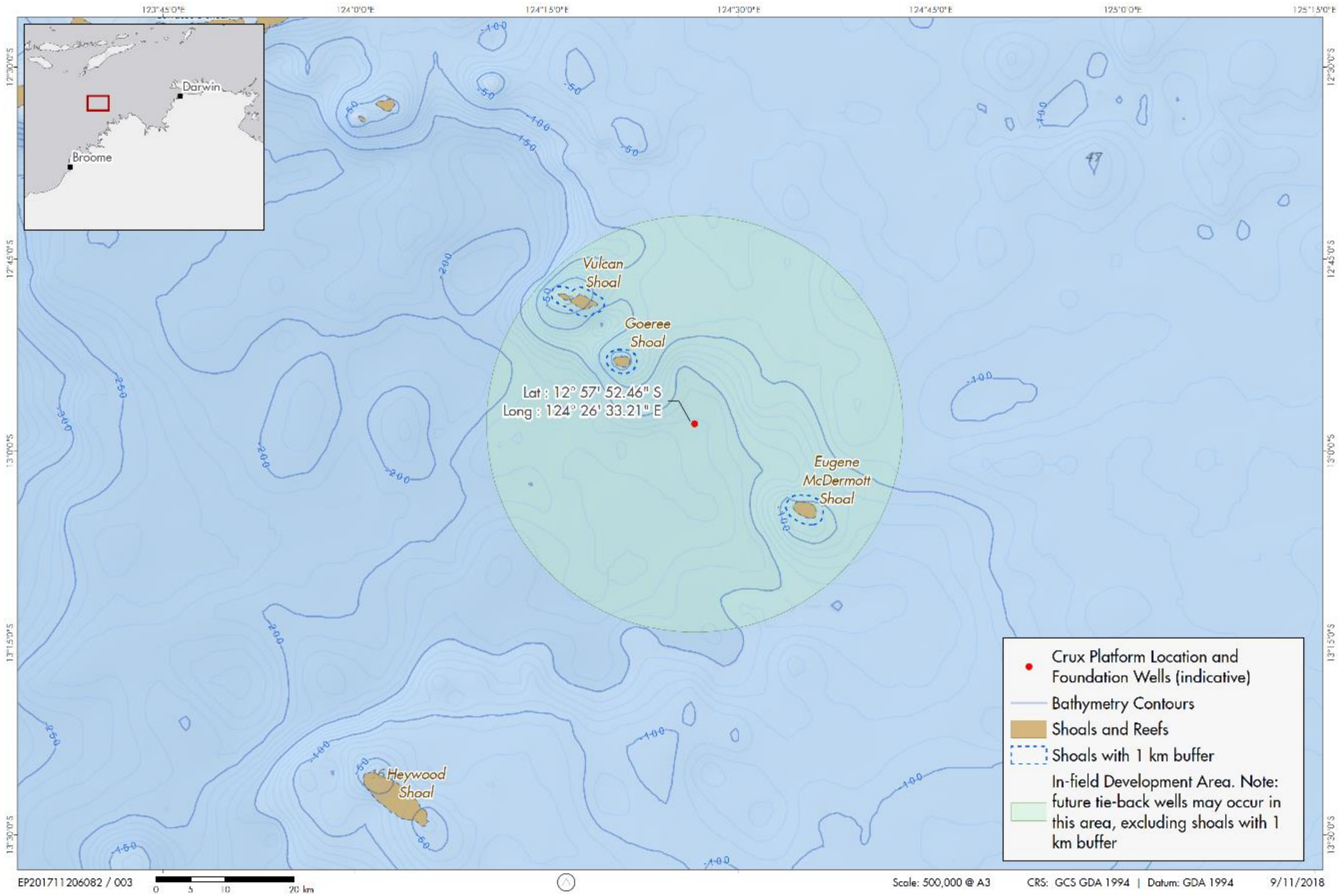



Figure ES-3: In-field Development Area


Figure ES-4: Export Pipeline Corridor

### Project Schedule

The Front End Engineering Design (FEED) engineering for the project commenced in 2019 with the Financial Investment Decision (FID) currently anticipated to occur in 2020. From FID it will take approximately 4 to 5 years for the platform to be fully designed, constructed off-site and towed to location. Whilst the platform is being built, the subsea production wells would be drilled and suspended until installation of the platform facilities, after which the wells would be completed, hooked-up to the platform and brought online.

The Crux platform will have a design life of 20 years. However, subject to the future investment decisions, operations may extend project life.

Decommissioning will be undertaken at the end of field operations.

### Project Stages

The key execution stages of the project are:

- development drilling, including tie-back and dry tree completion
- installation of the platform jacket and topsides
- installation and hook up of export pipeline and subsea integration system to the platform facilities
- commissioning
- operations and maintenance (note, this includes any future subsea tie-back developments within the in-field development area), and
- decommissioning.

The key activities within these project stages are summarised in **Table ES-0-1**.

Additional gas fields within the in-field development area may be tied back to the Crux platform. The development of these fields will broadly involve the same key stages and activities as those used in the development of the Crux field, with the exception of completion with subsea trees.

Table ES-0-1: Crux Project Stages and Key Activities

| Project Stage | Key Activities |
|---|---|
| Development drilling – including well tie-back to the platform and well completion | • Drilling and temporary suspension of production wells<br>• Foundation wells tied-back and completed with dry tree using a Modular Platform Rig temporarily installed on the Crux platform<br>• Wells perforated and unloaded with a coiled tubing unit and a temporary test package |
| Installation and hook-up of platform, export pipeline and subsea integration system | • Transport, installation and piling of jacket<br>• Transport and installation of platform topsides<br>• Installation and pre-commissioning (e.g. hydrotesting and dewatering) of export pipeline<br>• Installation of subsea integration system, including Crux pipeline end termination, Prelude pipeline end manifold and risers. |
| Commissioning | • Commissioning testing and monitoring topside equipment on the platform and the export pipeline |
| Operations and maintenance | • Well, flowline and riser operations<br>• Remote production and processing operations<br>• Planned maintenance and shutdown campaigns |

| Project Stage | Key Activities |
|---|---|
| | • During operations, additional fields within the in-field development area may be developed. Key activities associated with the development of these fields may include:<br>○ Installation and commissioning of subsea facilities to support future subsea tie-backs<br>○ Installation and commissioning of future compression module |
| Decommissioning | • Well abandonment<br>• Decommissioning of the platform<br>• Decommissioning of subsea facilities and export pipeline |

### Key Project Aspects

Key aspects associated with project activities that can interact with the environment are summarised below:

- **Physical presence** – The physical presence of the project will arise from the installation of physical features, such as wells, well tie-back infrastructure, subsea facilities and the export pipeline, and from the presence of the Crux platform and project vessels.
- **Vessel movements** – A number of vessels will be required throughout the project to undertake specific activities. Vessel movements within the project area are expected to be highest during the installation phase of the project.
- **Light emissions** – Artificial light from activities associated with the project will result in light spill to the surrounding marine environment. Light emissions are anticipated to be highest primarily during commissioning and start-up and upset conditions due to the increased presence of vessels and requirement for flaring during commissioning activities. Lighting of the platform will be reduced to a minimum during periods when the facility is not occupied.
- **Underwater noise** – Underwater noise will be produced during all stages of the project from development drilling, installation activities, vessel and helicopter movements, and decommissioning activities. The main sources of noise will be from pile driving activities for the installation of the platform foundations, and from vessel engines and machinery.
- **Atmospheric emissions** – Atmospheric emissions associated with the project will be generated by a number of sources, including combustion emissions from power generation and processing facilities, periodic flaring of gas during development drilling, commissioning/start-up and shutdown activities, operation of a pilot flame on the flare during operations for safety reasons, disposal of triethylene glycol (TEG) regeneration off gas stream to flare, transportation emissions, and fugitive emissions.

  As the Crux project development concept is premised on providing a supply of back-fill gas for the continued operation of the Prelude FLNG facility, the majority of the emissions are accounted for in the design and operation of the Prelude FLNG facility and have been subject to prior assessment and approval through the Prelude FLNG Environmental Impact Statement and subsequent EPs. This OPP addresses emissions specific to the Crux project.
- **Invasive marine species** – The drilling rig, vessels and equipment sourced from outside Australian waters have the potential to introduce or transport invasive marine species (IMS) to the project area, or potentially to other areas through activities such as support vessel interaction with the project area.

- **Liquid discharges** – Liquid discharges will be released to the marine environment throughout the life of the project. Key discharge streams include Produced Formation Water (PFW), wastewater (domestic sewage, greywater, bilge and deck drainage) and utility cooling water (vessels only), hydrotest water, and drill fluids/cuttings discharge.
- **Waste management** – Hazardous and non-hazardous solid wastes (except drilling cuttings and fluids, sewage and putrescible waste) and recyclable materials will be removed from the project area and returned to shore for processing.
- **Emergency events** – Emergency events are incidents that have the potential to trigger impacts that would otherwise not be anticipated during the normal and planned activities. In this OPP, this covers the potential for unplanned events (i.e. accidents or emergencies) resulting in potential large-scale releases of hydrocarbons. While of low probability of occurrence, the consequence has been assessed, and a proposed management framework defined for future implementation.

**Assessment of Alternatives**

The potential for tie-back of Crux and other nearby gas fields to Prelude FLNG was flagged as part of the Prelude environmental approvals. Concept Select studies have focused on the backfill opportunities presented for the Prelude FLNG host.

In progressing the Crux project, Shell has undertaken a range of alternative options to inform Concept Select. The Fixed Platform concept was identified as the optimal host type for Crux. It provides inherently lower HSSE exposure and a higher capital efficiency than Floating Production Storage and Offloading (FPSO) concepts.

The decision for the selection of the manning philosophy for the Crux platform gave consideration to the optimum combination of capital efficiency and personnel risk exposure, with NNM platform identified to be optimal to achieve these objectives. The processing facilities required for the platform-based concept are significantly reduced compared to an FPSO concept. Simplification of the topsides facilities and associated reduction in maintenance requirements and manhours provides the opportunity to operate the platform remotely while maintaining the facilities on a campaign maintenance basis.

Shell has also evaluated other alternatives in design that have been key to informing the Crux project, including options for PFW management, carbon dioxide ($CO_2$) management and power generation. These are presented in the OPP.

## Description of the Existing Environment

The OPP describes the key physical, biological, socio-economic and cultural characteristics of the existing environment relevant to the Crux project, including MNES as defined under the EPBC Act.

The existing environment has been described in the context of two areas:

- the **project area**, which consists of the in-field development area and export pipeline corridor (as shown in **Figure ES-3** and **Figure ES-4**), and
- the potential **area of influence** associated with the project. This is informed by the maximum extent of the exposure zone (i.e. low threshold) for hydrocarbons released to the marine environment from the maximum credible spill scenarios that may occur throughout the life of the project. This is a conservative outer estimate, based on a low probability potential for unplanned discharge.

Shell has commissioned a number of baseline studies to characterise the existing marine environment relevant to the project. These baseline studies built on the knowledge undertaken through the Applied Research Programme (ARP) in collaboration with the Australian Institute of Marine Science (AIMS) and industry partner INPEX. These studies included metocean monitoring, baseline studies for water quality, sediment and infauna, benthic habitats and seabed geotechnical conditions.

A summary of the existing environment relevant to the Crux project is provided below, with a full description provided in the OPP.

**Physical Environment**

Water depths at the in-field development area range between approximately 90 m and 180 m. The seabed is generally relatively flat with a gentle gradient falling from the north-east toward the deeper south-west corner. Along the export pipeline, the general bathymetric profile is characterised by an overall increase in depth in a south-westerly direction, reaching a maximum depth of approximately 280 m.

Climate, oceanography, bathymetry and seabed features, water and sediment quality, air quality and underwater noise are all typical of the region.

**Ecosystems, Communities and Habitats**

There are no known offshore reefs or islands within or in close proximity to the project area. However, there are a number of emergent oceanic reefs and islands offshore of northern Australia. The main offshore reefs and islands in the region include Ashmore Reef (155 km north-west of the Crux platform), Cartier Island (105 km north-west of the Crux platform), Hibernia Reef (160 km from the Crux platform), Browse Island (158 km south-west of the Crux platform), Seringapatam Reef (270 km south-west of the Crux platform), Scott Reef (290 km south-west of the Crux platform) and Adele Island (314 km to the south-west).

There are a large number of shoals and banks within the Browse Basin and open offshore waters off northern Australia. The shoals closest to the project area are:

- Goeree Shoal – located within the in-field development area with a 1 km exclusion buffer around the shoal, approximately 13 km north-west of the Crux platform
- Eugene McDermott Shoals – located within the in-field development area with a 1 km buffer, approximately 18 km south-east of the Crux platform,
- Vulcan Shoal – located within the in-field development area with a 1 km buffer, approximately 22 km north-west of the Crux platform
- Barracouta Shoals – located approximately 63 km north-west of the Crux platform
- Heywood Shoals – located approximately 67 km south-west of the Crux platform and approximately 21 km from of the export pipeline corridor at the closest point, and
- Echuca Shoals – located approximately 117 km south-west of the Crux platform and approximately 53 km north of the export pipeline corridor.

While the in-field development area has an outer radius of 30 km from the current proposed platform location, a 1 km exclusion buffer from around shoals within this area has been defined in order to avoid potential impacts to these features.

A large outcropping reef area was identified in the north-eastern section of the in-field development area. A review of bathymetry at a regional level has identified that the outcropping reef feature forms part of an extensive seabed ridge that occurs at an average depth of approximately 100 m.

The Crux platform is located 190 km from the nearshore and coastal environments of the Kimberley on the WA coastline.

The OPP presents a review of the Key Ecological Features (KEFs) that occur within or adjacent to the project area and area of influence. Only one KEF is intersected by the Crux project, with the export pipeline intersecting a small portion of the continental slope demersal fish communities. The other KEFs are only relevant in the context of the area of influence and are assessed in the OPP as relevant to unplanned discharges.

### Threatened Species and Ecological Communities

An online EPBC Protected Matters Database Search was conducted for the in-field development area, export pipeline corridor and area of influence. A summary of the results is presented below:

- in-field development area – the search identified 20 listed threatened fauna species and 33 listed migratory species (17 of which are also listed as threatened) that may occur or have habitat in the area,
- export pipeline corridor – the search identified 20 listed threatened fauna species and 33 listed migratory species (17 of which are also listed as threatened) that may occur or have habitat in the area. All listed threatened and migratory species in the in-field development area were also identified as occurring in the export pipeline corridor.
- area of influence – the search identified 41 listed threatened fauna species and 89 listed migratory species (27 of which are also listed as threatened) that may occur or have habitat in the area.

A review of the DoEE National Conservation Values Atlas determined that the in-field development area is located within a biologically important foraging area for whale sharks although the published Conservation Advice and tagging studies indicate this is more likely to be a migration corridor than a significant foraging area. No other biologically important areas are intersected or overlapped by the project area.

### Socio-economic and Cultural Environment

Given the remote distance of the proposed Crux platform (approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome), there are limited socio-economic interactions, and expected to be primarily related to other marine users (specifically other marine traffic, oil and gas facilities and commercial fishing).

It is expected that the Crux project will utilise the onshore facilities (Broome and Darwin) used to service the Prelude FLNG facility, and leveraging the established supply chain, logistics and community partnerships that have been embraced by Shell and its supply chain partners to date.

There are no World Heritage properties in, or in the immediate surrounds of, the project area. Similarly, there are no National Heritage properties or Ramsar wetlands in, or in the immediate surrounds of, the project area.

The project area does not overlap with any Australian Marine Parks (AMPs). However, there are a number of AMPs within the area of influence, which are assessed in the OPP as relevant to unplanned discharges.

The project area overlaps with a variety of Commonwealth and WA State commercial fishing management areas, and the OPP identifies fisheries interests within the broader area of influence. Commercial fishing is typically concentrated mostly in coastal waters and minimum fishing effort is known to occur within the vicinity of the project area, given its remoteness offshore.

There are no major shipping routes traversing the in-field development area or export pipeline corridor. The nearest major shipping channel is approximately 560 km to the west of the proposed Crux platform.

The petroleum exploration and production industry is a significant user of offshore waters in northern WA, particularly within and adjacent to the Browse and Northern Bonaparte basins. The closest facility to the proposed Crux platform is the Montara production FPSO facility, which is located approximately 36 km north. The Ichthys project offshore facilities are located approximately 164 km to the south-west of the proposed Crux platform, and the Prelude FLNG facility is approximately 165 km to the south-west of the Crux platform, representing the location where the export pipeline will feed into.

## Definition of Acceptable Levels for the Crux Project

The OPGGS (E) Regulations require the proponent to include an evaluation of all the impacts and risks, that reaches a conclusion on whether the impacts and risks will be of an ‘acceptable’ or ‘unacceptable’ level. To this end, Shell has determined acceptable levels of impact to the environmental receptors that may credibly be impacted by the Crux project.

The following were considered when establishing the acceptable levels of impacts and risks outlined in the impact evaluation:

- the principles of ecologically sustainable development (ESD).
- other requirements applicable to the Crux project (e.g. laws, policies, standards, conventions etc.), including significant impacts to MNES. In this context, specific reference to the Significant Impact Criteria under EPBC Act guidance has been defined.
- internal context, including Shell’s environment policy, environmental risk management framework, technical guidance material and opinions of internal stakeholders, and
- external context, including any available information provided by stakeholders during the preparation of the Crux OPP.

## Evaluation of Project Environmental Impacts and Risks

The OPP documents the process that identifies and evaluates potential environmental impacts and risks and develops means of mitigating the impacts of the proposed Crux project on the environment, including socio-economic, cultural and human health impacts.

It describes the approach undertaken to evaluate the magnitude of impact to environmental and social receptors from activities associated with the Crux project. This description includes the identification of potential impacts and benefits, and the evaluation of their significance.

The risk and impact assessment approach is based on Shell’s standardised Hazards and Effects Management Process, which is consistent with the principles outlined in the Australian Standard AS/NZS ISO 31000:2009 Risk Management and Handbook 203:2006 Environmental Risk Management.

A summary of the relevant environmental impacts and risks presented in the OPP is provided in **Table ES-2**.

The acceptability of the impacts and risks associated with each of the aspects of the Crux project was assessed. Shell applies the following process to demonstrate acceptability of residual impacts and risks (i.e. taking into account management measures):

- residual planned impacts that are ranked as minor or less (i.e. minor, slight, no effect or positive effect) and residual risks for unplanned events ranked negligible and minor, are inherently 'acceptable', if they meet legislative and Shell requirements and the established acceptable levels of impacts and risks.
- moderate residual impacts, and moderate and major residual risks, are ‘acceptable’ if good industry practice can be demonstrated. In this acceptability evaluation, in addition to the considerations above, the following points are also considered:
  - internal context – the proposed controls are consistent with Shell policies, procedures and standards
  - external context – consideration of stakeholder expectations, objections and claims, and
  - other requirements – the proposed controls are consistent with national and international standards, laws and policies.
- major and massive magnitude effects from planned impact, and massive residual risks from unplanned risks, are ‘unacceptable’.

The residual impacts and risks for each aspect of the Crux project were determined to be acceptable following implementation of the key management controls, as outlined in **Table ES-2**.

Table ES-2: Summary of Environmental Impacts and Risks Relevant to the Crux Project

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| Physical presence and vessel movements | Planned impacts resulting from the physical presence of the Crux project, including:<br>• drilling of the foundation wells with a moored semi-submersible drilling rig<br>• physical presence of the Crux platform, export pipeline and subsea integration system,<br>• presence of project vessels and vessel movements, and<br>• seabed disturbance from project footprint. | Minor | All project vessels operating within the project area will adhere to the navigation safety requirements contained within the International Regulations for Preventing Collisions at Sea 1972 (COLREGS), Chapter 5 of The International Convention for the Safety of Life at Sea 1974 (SOLAS Convention), International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention), the *Navigation Act 2012* and any subsequent Marine Orders, which specify standards for crew training and competency, navigation, communication, and safety measures.<br>Maintenance of a minimum 1 km buffer from shoals within the in-field development area.<br>Vessels will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans, (except in emergency conditions or when manoeuvring is not possible, such as in the case of pipelay activities), which include:<br>• implement a caution zone of 150 m for dolphins and 300 m for whales<br>• vessels will not knowingly approach closer than 100 m to a whale and 50 m for a dolphin (i.e. no approach zone)<br>• make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale<br>• vessels will not knowingly travel > 6 knots within the caution zone of a whale or dolphin, and<br>• there will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone).<br>All areas of the seabed disturbed by installation activities will be surveyed prior to installation. (The Crux NNM platform location and export pipeline corridor have been surveyed as part of the baseline environmental studies for the Crux project and no sensitive seabed features were observed).<br>Validate that the Crux platform, export pipeline and subsea integration system facilities are laid according to planned locations within allowable tolerances. | ***Physical and Biological Environment***<br>Direct impacts to benthic habitats from the Crux project will be limited to < 0.1% of the total project area.<br>Impacts to the continental slope demersal fish communities KEF will be limited to <1% of the total area of the KEF.<br>No direct loss of coral communities (coral colony) at Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal will occur as a result of the Crux project.<br>***Threatened Species and Ecological Communities***<br>No collisions between project vessels and marine fauna resulting in mortality or injury of species listed as threatened or migratory under the EPBC Act will occur within the Crux project area.<br>***Socio-economic Environment***<br>No adverse interactions between Shell's activities within the Crux project area and other marine users.<br>Displacement of other marine users within the Crux project area restricted to: |
| | Unplanned risks resulting from the physical presence of the Crux project, including:<br>• presence of project vessels and vessel movements – collision with marine fauna. | Minor | | |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | An anchoring plan will identify suitable areas for anchors to be placed within the in-field development area and will confirm no anchoring on shoals or within the associated 1 km buffer.<br>If future tie-backs are proposed within 2 km of the shoals or on the outcropping reef feature within the Crux in-field development area, then additional studies will be undertaken to further characterise the benthic habitats within the proposed disturbance area. The studies will inform an assessment of the acceptability of the impacts, particularly with regard to disturbance of any hard seabed substrates that contain high biodiversity value.<br>Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners.<br>*Decommissioning*<br>Development and implementation of a project decommissioning plan which considers environmental impacts and risks.<br>Prior to the end of operating life, a comparative assessment of potential decommissioning options will be undertaken to inform the development of a Decommissioning EP that will be submitted to NOPSEMA. The comparative assessment will consider the merits of each option in the context of health, safety and environmental protection, technological feasibility, local capacity, regulatory compliance, public participation and economic stewardship within a broader ALARP framework to inform selection of the preferred decommissioning strategy.<br>The Decommissioning EP will present the outcomes of the comparative assessment and include an ALARP and acceptability assessment of the preferred option. The acceptability assessment will consider ESD, industry standard at the time and stakeholder expectations. The Decommissioning EP will be implemented for the duration of the decommissioning activities. | • temporary displacement from project activities, and<br>• exclusion from gazetted Petroleum Safety Zones.<br>Other marine users will be provided with information on the timing, nature and scale of aspects of the Crux project through Shell's consultation program. |
| Light emissions | Planned impacts resulting from light emissions arising from the Crux project. | Minor | External lighting on offshore facilities/infrastructure will be minimised through design to that required for navigation, safety of deck operations and security considerations, except in the case of an emergency.<br>Flaring during operations is optimised to enable the safe and economically efficient operation of the facility. | ***Biological Environment***<br>No mortality or injury of threatened and migratory MNES species as a result of artificial light emissions from the Crux project. |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| Underwater noise | Planned impacts resulting from underwater noise generated during the Crux project, including:<br>• piling<br>• Vertical Seismic Profiling (VSP)<br>• operations, and<br>• vessels. | Minor | Any VSP activities conducted at the development well will comply with 'Standard Management Procedures' set out in EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines (or the contemporary requirements at the time of the activity), specifically:<br>• pre-start-up visual observations. Visual observations for the presence of whales by a suitably trained crew member will be carried out at least 30 minutes before the commencement of VSP.<br>• start-up and normal operating procedures, including a process for delayed start-up, should whales be sighted. Visual observations by trained crew should be maintained continuously.<br>• night time and low visibility procedures.<br>Pile driving activities conducted for the Crux platform foundations will comply with 'Standard Management Procedures' set out in EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines, specifically:<br>• pre-start-up visual observations. Visual observations for the presence of whales by a trained marine mammal observer will be carried out at least 30 minutes before the commencement of pile driving.<br>• start-up and normal operating procedures, including a process for delayed start-up, should whales be sighted. Visual observations by a trained marine mammal observer should be maintained continuously.<br>• shut-down procedures. Piling will be stopped should whales come within 500 m of the pile driving barge.<br>• night time and low visibility procedures.<br>• in addition to the 'Standard Management Procedures' identified above, Shell will commit to at least one trained marine mammal observer being present on the pile driving barge for the duration of pile driving activities for the Crux platform foundations.<br>Maintenance of a minimum 1 km buffer from shoals within the in-field development area. | ***Threatened Species and Ecological Communities***<br>No mortality or injury of threatened and migratory MNES species as a result of underwater noise from the Crux project. |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| Atmospheric and greenhouse gas emissions | Planned impacts resulting from atmospheric emissions arising from the Crux project, including:<br>• decline in local or regional air quality, and<br>• contribution to the incremental build-up of greenhouse gas (GHG) in the atmosphere. | Minor | All drilling rigs, vessels and Crux platform (as appropriate to vessel class) will comply with International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI (Prevention of air pollution from ships), the *Navigation Act 2012*, the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsequent Marine Orders. which requires vessels to have a valid IAPP Certificate (for vessels > 400 tonnage) and use of low sulphur fuel, when possible.<br>Complete and submit annual National Greenhouse and Energy Reporting (NGER) reports during the operations stage of the project for the Kyoto Protocol listed (or applicable post-Kyoto agreement at the time of operations) GHG emissions on a $CO_2$ equivalency basis for each facility (as defined in Section 9 of the *National Greenhouse and Energy Reporting Act 2007* and National Greenhouse and Energy Reporting Regulations 2008) by fuel type, and the relevant requirements of the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015.<br>In the event that the safeguard mechanism baseline for the project is exceeded, Shell will follow requirements outlined under the safeguard mechanism and, where required, purchase and surrender Australian carbon credit units.<br>GHG and National Pollutant Inventory reporting records (or contemporary requirements at the time of the activities) will be complied with during the project.<br>Flaring during operations is optimised to enable the safe and economically efficient operation of the facility.<br>Selection of gas turbine generators during design process considers energy efficient (i.e. low emission) equipment, in alignment with the selected concept.<br>Tri-ethylene glycol off gas will not be vented but sent to the flare for combustion as long as the flare is ignited.<br>During operations of the Crux facility, regular reviews of GHG opportunities will be reviewed and adopted where appropriate. | ***Physical Environment***<br>No significant decline in air quality at residential or sensitive populations as a result of atmospheric emissions from the Crux project.<br>Atmospheric emissions associated with all drilling rigs, project vessels and the Crux platform to comply with MARPOL Annex VI requirements.<br>Atmospheric emissions associated with the project will be consistent with national and international mechanisms for the management of GHG emissions for the life of the project.<br>***Socio-economic and Cultural Environment***<br>Emissions at the Crux facility will not exceed 0.5 Mt CO2-e in any single operating year.<br>Emissions at the Crux facility will not exceed an average of 0.4 Mtpa CO2-e over a 5-year period.<br>Emissions at the Crux facility will comply with the Australian government safeguard mechanism baseline.<br>Shell Australia will ensure that programs are developed and implemented, in conjunction with the wider Shell Group and |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | | others, to actively support the global transition to a lower carbon future by net displacement of higher carbon intensity energy sources relating to third party GHG emissions. |
| Invasive marine species | Unplanned risks associated with the introduction of invasive marine species (IMS) as a result of the Crux project. | Moderate | Ballast water exchange operations will comply with the International Maritime Organisation (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (as appropriate to vessel class), Australian Ballast Water Management Requirements, *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and *Biosecurity Act 2015*, including:<br>• all ballast water exchanges conducted > 12 nautical miles from land<br>• vessel Ballast Water Management Plan stipulating that ballast water exchange records will be maintained, and<br>• completion of Department of Agriculture and Water Resources Ballast Water Management Summary sheet for any ballast water discharge in Australian waters).<br>Biofouling management for vessels in accordance to the IMO Guidelines for the Control and Management of Ships Biofouling to Minimise the Transfer of Invasive Aquatic Species.<br>The International Convention on the Control of Harmful Anti-fouling Systems on Ships will be complied with, including vessels (of appropriate class) having a valid International Anti-Fouling System Certificate.<br>Compliance with the Commonwealth *Biosecurity Act 2015*, WA *Fish Resources Management Act 1994* and *Aquatic Resources Management Act 2016*, NT *Fisheries Act* and associated regulations.<br>Alignment with the *National biofouling management guidance for the petroleum production and exploration industry*, and the WA Department of Primary Industries and Regional Development *Biofouling Biosecurity Policy.* | ***Ecosystems, Communities and Habitats***<br>No IMS of concern established in the natural environment as a result of the Crux project.<br>No introduction of IMS to the marine environment from ballast water exchange operations undertaken or biofouling by project vessels. |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | Maintenance of a minimum 1 km buffer from shoals within the in-field development area.<br>The Crux platform and jacket will not be wet towed to the Crux in-field development area. | |
| Waste management | Unplanned risks resulting from an accidental release of hazardous or non-hazardous solid waste to the marine environment. | Slight | All discharge of waste from vessels will comply with relevant MARPOL 73/78, *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification).<br>Waste management procedures will be implemented for the Crux project that:<br>• provide for waste segregation and storage<br>• safe handling and transport of waste, and<br>• appropriate waste classification and disposal, recycling and landfill.<br>The disposal of non-hazardous and hazardous wastes will be tracked to confirm they are disposed of at an appropriately licensed waste facility.<br>The management and disposal of any quarantine risk material will be in accordance with relevant requirements of the *Biosecurity Act 2015*. | ***Threatened Species and Ecological Communities***<br>No mortality or injury of threatened and migratory MNES species as a result of unplanned waste discharge to sea during the Crux project. |
| Liquid discharges | Planned impacts resulting from planned liquid discharges from the Crux project, including:<br>• PFW (including non-routine discharges of off-specification PFW)<br>• wastewater<br>• hydrotest water, and<br>• drilling fluids and cuttings. | Minor | *Utility Discharges*<br>All planned discharges from vessels will comply with relevant requirements of MARPOL 73/78, the *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and any subsequent Marine Orders requirements (as appropriate for vessel classification).<br>The Crux platform deck drainage shall be managed to reduce impacts on the environment.<br>Oily bilge water from machinery space drainage is treated to a maximum concentration of 15 ppm oil-in-water prior to discharge from vessels, as specified in MARPOL 73/78 (Annex I).<br>Offshore discharge of sewage from vessels will be in accordance with Marine Order 96. | ***Physical and Biological Environment***<br>No measurable impacts to sediment quality or water quality in the region from liquid discharges during the Crux project.<br>The area influenced by routine operational discharges is expected to be limited to within 1 km of the liquid discharge locations.<br>Discharges at the Crux platform may result in impacts to water and sediment quality, |
| | Unplanned risks resulting from accidental liquid discharges during the Crux project, including: | Moderate | | |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | • minor accidental releases of chemicals/hydrocarbons to the environment. | | Food wastes will be macerated to < 25 mm particle size whilst operational prior to discharge to sea, in accordance with Marine Order 95.<br>Containment around liquid hydrocarbon storage tanks will be installed on the Crux platform to reduce the potential for minor accidental releases of chemicals/hydrocarbons to the environment.<br>*Chemical Discharges*<br>For chemicals planned to be used in production and process (including in the subsea facilities and well) and for hydrotesting, and which will be discharged to the marine environment, will be selected in accordance with the Chemical Management Process for chemical selection and assessment of effects on the environment.<br>*Hydrotest Water Discharges (Crux export pipeline)*<br>An evaluation will be undertaken prior to hydrotesting of the Crux export pipeline to inform the selection of the discharge location of the pipeline hydrotest water (i.e. Crux versus Prelude end of the pipeline). The evaluation will include a comparison of environmental impacts between the two discharge locations, to determine which location has the lowest environmental impact. The evaluation will also consider safety and technical factors as part of the decision making process.<br>*Produced Water Discharges*<br>An environmental monitoring program and adaptive management framework will be developed for PFW. The monitoring program will include:<br>• continuous monitoring, whilst available, of PFW discharge volume (online flow meter) and dispersed oil-in-water (online oil-in-water analyser)<br>• chemical characterisation of PFW – WET testing will be completed when a suitably representative PFW sample of normal operations can be taken, and then on a risk-based approach thereafter<br>• additional monitoring as a result of trigger actions, and<br>• periodic environment monitoring within the in-field development area. | both of which are components of the Commonwealth marine environment, within 1 km of the Crux platform or drilling locations. Impacts to water and sediment quality beyond this range are unacceptable.<br>PFW discharges from the Crux platform will meet relevant ANZECC & ARMCANZ guidelines 95% species protection levels for sediment and water quality and/or be within natural variation or background concentration beyond the predicted mixing zone(s) under normal operations.<br>Direct impacts to benthic habitats from the Crux project will be limited to < 0.1% of the total project area.<br>No mortality or injury of threatened and migratory MNES species as a result of liquid discharges during the Crux project.<br>Impacts from liquid discharges from the Crux project on the ccontinental slope demersal fish communities KEF will be limited to <1% of the total area of the KEF.<br>No direct loss of coral communities (coral colony) at Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal will occur as a result of |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | The oil-in-water concentration of PFW will be continuously monitored by an online analyser, while available, which will be fitted with an alarm that activates if the oil-in-water concentration is > 30 mg/L.<br>Calibration of the online analyser will be undertaken regularly during the initial early operations phase.<br>*Drilling Fluid and Mud Discharges*<br>No planned discharge of whole SBM will occur during development drilling.<br>When using SBM, the solids control equipment will reduce the residual base fluid on cuttings content prior to discharge overboard.<br>Residual SBM on cuttings will be less than 10% by weight (w/w), averaged over all well sections using SBM.<br>If drilling for future tie-backs is proposed within 2 km of the shoals within the Crux in-field development area, then additional modelling will be undertaken. The concept select for any future tie-backs will use the results of the modelling to inform selection, to achieve acceptable impacts.<br>Should new regionally relevant information become available that provides scientific evidence that 2 km is not a suitably conservative buffer to protect drill cuttings and fluid impacts on coral communities at the shoals as related to tie-backs, Shell will apply an adaptive management approach informed by further validation modelling. | liquid discharges from the Crux project.<br>No direct loss of coral communities on the outcropping reef feature will occur as a result of the discharge of drill fluids and cuttings for future tie-back wells within the Crux in-field development area. |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| Unplanned spills | Unplanned risks resulting from a worst-case credible spill scenario from:<br>• loss of well control<br>• loss of process storage tank containment<br>• loss of containment from export pipeline, and<br>• loss of fuel from vessel. | Major | Vessel specific controls will align with MARPOL 73/78, the *Navigation Act 2012,* the *Protection of the Sea (Prevention of Pollution from Ships Act 1983* and subsequent Marine Orders (as appropriate for vessel classification), which includes managing spills aboard, emergency drills and waste management requirements.<br>All vessels involved in the project will have a valid Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan (as appropriate for vessel classification) which is maintained including: Spill Kit – Pollution Control Equipment container/ box is located at a strategic location, containing adequate equipment/material (minimum as per the Shipboard Oil Pollution Emergency Plan) to control spills of pollutants on board.<br>All project vessels operating within the project area will adhere to the navigation safety requirements contained within the COLREGS, Chapter 5 of the SOLAS Convention, STCW Convention, the *Navigation Act 2012* and any subsequent Marine Orders, which specify standards for crew training and competency, navigation, communication, and safety measures.<br>Offshore Vessel Inspection Database or equivalent reviewed prior to mobilisation of project vessels.<br>Australian Hydrographic Service notified of location of installed infrastructure to facilitate inclusion on nautical charts.<br>Australian Hydrographic Service advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners.<br>Accepted WOMP in place for all wells, in accordance with the OPGGS Act requirements. The WOMP will outline the barriers in place throughout the construction and operation of the well to prevent a loss of well control. For development drilling, the WOMP will include:<br>• maintaining overbalance in the well through the use of weighted drilling fluids,<br>• installation of a Blowout Preventer (BOP) during drilling operations of the bottom hole sections, and<br>• regular testing of BOP.<br>Accepted EPs and Oil Pollution Emergency Plans (OPEPs) in place for all petroleum activities appropriate to the nature and scale of the | No emergency events associated with the unplanned release of Crux condensate or vessel fuel to the marine environment during the Crux project. |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | credible hydrocarbon spill risks. The OPEP include an Operational and Scientific Monitoring Program will be initiated and implemented as appropriate to the nature and scale of the spill and the existing environment, as informed by a net environmental benefit assessment. The OPEP shall consider:<br>• relief well planning and preparedness<br>• interim source control (e.g. capping stacks for subsea well blowouts)<br>• oiled wildlife response, and<br>• operational and scientific monitoring.<br>Stakeholder consultation throughout the Crux project, including consultation consistent with the requirements of the OPGGS (E) Regulations for all subsequent petroleum activities and associated EPs.<br>Where vessel dynamic positioning systems are required, they shall be in working order whilst within the Crux platform safety zone at all times.<br>Development and implementation of a maintenance management system for the Crux platform, export pipeline and subsea infrastructure.<br>Development of simultaneous operations (SIMOPS) plans where interactions with other activities (e.g. Prelude operations, backfill installations) may credibly occur.<br>Concrete coating of the pipeline reduces the risk of a dropped object damaging the pipeline.<br>The Crux platform will have controls/systems in place that will assist with the early detection of spills/leaks from the NNM platform, including:<br>• fire and gas system,<br>• satellite monitoring of the Crux platform location, and<br>• continuous process control monitoring system (assist in detection of significant leaks).<br>Assess feasible design and monitoring controls that will assist with the early detection of spills/leaks from the Crux platform. Controls that are considered compatible with the NNM philosophy will be | |

| Aspect | Project Component/Activity | Residual Impact/ Risk | Key Management Controls | Environmental Performance Outcomes |
|---|---|---|---|---|
| | | | implemented, unless it can be demonstrated that the ‘cost’ is grossly disproportionate to the benefit gained.<br>Selection of key material will take corrosion into account.<br>Pigging of the Crux gas export pipeline will be undertaken as required throughout operations to detect defects, assess integrity and enable risk based management of the pipeline.<br>Fuel type will be considered in the construction vessel contracting process where alternatives to marine diesel are being considered. | |

### Cumulative Impacts

The potential for cumulative impacts and risks resulting from the Crux project were considered from two perspectives:

- How might aspects from the Crux project compound with aspects of existing activities within the Timor Sea region?
- How might an environmental receptor be affected by multiple aspects of the Crux project and other activities?

Given the low likelihood of unplanned events that may arise during the Crux project (e.g. large hydrocarbon spills), unplanned events have not been considered in the assessment of cumulative impacts.

The aspects-based cumulative impact assessment considered how the aspects from the Crux project, and the associated environmental impacts and risks, may interact with aspects from other activities in the region to result in increased environmental risks and impacts. Other activities identified included:

- the Prelude FLNG facility
- the Montara production facility
- Ichthys offshore production facility, and
- commercial shipping.

The planned aspects identified that were common to these activities and the Crux project were:

- physical presence and vessel movements
- light emissions
- atmospheric emissions, and
- liquid discharges.

The receptor-based assessment of cumulative impacts considered how multiple aspects of the Crux project may compound to increase the impacts for a given receptor. Receptors at susceptible to cumulative impacts include:

- water quality
- sediment quality
- benthic communities
- shoals and banks, and
- threatened species and ecological communities.

The Crux project will not result in any material cumulative impacts to the marine environment at a local scale as there is no significant overlap with other existing facilities. No cumulative impacts to key values and sensitivities are expected. The receptor-based cumulative impact assessment concluded that the potential for cumulative impacts from different aspects of the Crux project is low and confined to the waters, sediment and benthic habitats and communities in the immediate vicinity of the Crux platform. Therefore, the residual impact and risk rankings detailed in the previous aspect assessments remain unchanged.

Regional cumulative impacts may occur in terms of incremental increases in vessel movements and $CO_2$ emissions. However, these have been assessed as minor and do not change the residual risk rankings for any of the potential impacts assessed in this OPP.

The potential cumulative impacts to environmental receptors are low and will be largely restricted to the waters, sediment and benthic habitats and communities in the immediate vicinity of the Crux platform. Potential cumulative impacts, both aspect- and receptor-based, were all determined to be within the acceptable levels defined for the Crux OPP.

### Health Impacts

The anticipated health impacts associated with the Crux project with potential to affect any onshore communities, in particular the onshore logistics bases of Broome and Darwin, are expected to be very minor with due consideration of:

- the remote offshore context for this project. The majority of construction and operation activities are well offshore, 620 km from Broome and approximately 700 km from Darwin
- the logistical arrangements for transiting workers aim to minimise overnight stays in onshore locations, and seeking to utilise existing established supply chain logistics now in place for Prelude FLNG, and
- existing industrial areas will be utilised for bases in Broome and/or Darwin.

Given the offshore nature of the Crux project, the effects of Crux project on community health (e.g. community health services or workforce influx pressures) are expected to be very minor, even during high-activity periods such as construction.

Shell is committed to reducing the potential impacts of the Crux project on Australian communities, and intends to implement the following measures:

- an ongoing stakeholder engagement program will be undertaken as the project progresses through future phases of development planning and implementation.
- emergency planning will include early discussions with local health authorities on local community arrangements to provide appropriate support in the scenario of medical response.
- the Crux platform is designed to operate under a NNM concept, which will deliver benefits of minimal workforce requirements and commensurate minimal disturbance to onshore communities
- scheduling of flights in accordance with the Broome International Airport Fly Neighbourly Policy.
- Shell will aim to replicate Prelude planned flight considerations (flight plans/times), which are designed to minimise local disturbance:
  - no flights on Sundays
  - reduced number of flights on Saturday, and
  - flying route to avoid Roebuck Bay and local Aboriginal community (Mallingbar).
- Shell is considering local content and progressing an AIP plan as part of the development of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from health impacts relevant to the Crux project to be acceptable.

## Environmental Performance Framework

Shell will develop a health, security, safety and environmental management system (HSSE-MS) that encompass all stages of the Crux project. The HSSE-MS will provide the means that environmental risks and impacts from the Crux project are managed to a level that is acceptable and the EPOs described in this OPP achieved. Shell will draw on existing corporate policies, environmental systems and processes, which have been developed and improved continuously throughout Shell's considerable operational history. Elements of the implementation of the HSSE-MS include:

- contractor HSSE management process,
- competency requirements and assurance,
- environmental audits and assurance,
- management of incidents and non-conformances,
- emergency preparedness, including:
  - OPEPs, and
  - OSMPs.
- monitoring and measurement of emissions, discharges and environmental quality, including:
  - marine discharges, and
  - atmospheric emissions.

Given the intent of an OPP as an early stage, 'whole-of-project' approvals document, the EPOs defined for the Crux project are appropriately high-level, with a focus on the key environmental outcomes to be achieved commensurate to the impact/risk conclusions. Consequently, the environmental performance framework is also a high-level, and will be developed and refined as the design of the Crux project progresses.

Activity-specific EPs will be developed for all petroleum activities within the scope of the Crux EP, which will contain detailed EPOs, environmental performance standards, measurement criterial and detailed implementation strategy. The EPOs in the EPs will maintain an equivalent, or better, level of environmental performance.

# 1. Introduction

## 1.1. Introduction to the Crux Project

Shell Australia Pty Ltd (Shell), together with Joint Venture Participants Seven Group Holdings (SGH) Energy and Osaka Gas, is progressing planning for the prospective development of the Crux gas field, located approximately 160 km north-east of the Prelude field in the northern Browse Basin, offshore the Kimberley coast, Western Australia (WA) (**Figure 1-1**).

The Crux field is located in Commonwealth marine waters in the northern Browse Basin, 190 km offshore north-west Australia and 620 km north-north-east of Broome.

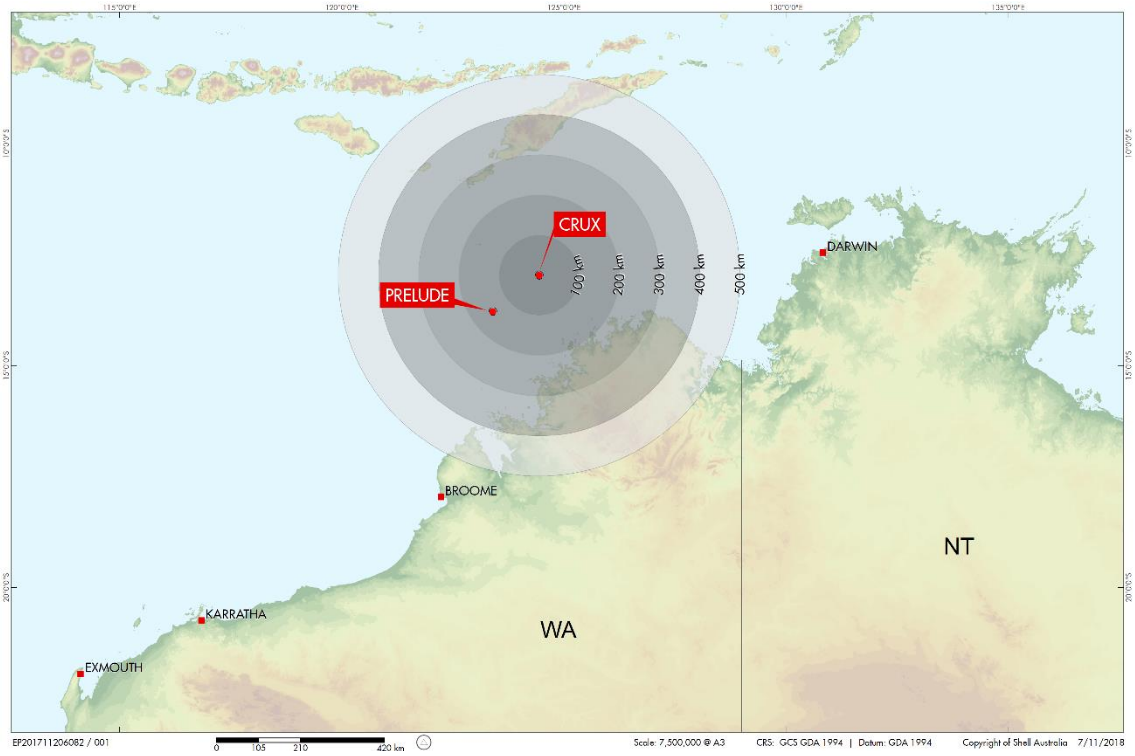



Figure 1-1: Location of the Crux Project

The Crux project has been identified as the primary source of backfill gas supply to the Prelude Floating Liquefied Natural Gas (FLNG) facility, previously approved under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), through decision EPBC 2008/4146. The Crux project will not result in any increase in production capacity of the Prelude FLNG facility. Rather, Crux will provide backfill capacity for the Prelude FLNG facility. In summary, the proposed Crux project consists of a Not Normally Manned (NNM) platform in 165 m water depth; with five production wells, minimal processing and utility systems, tied back to the existing Prelude FLNG facility via a 165 km 26-inch export pipeline. Crux will be operated remotely from the Prelude FLNG facility.

The current Crux project concept, shown in **Figure 1-2**, comprises:

- a NNM platform, which includes dry trees, processing facilities and associated utility systems
- five production wells with subsea wellhead system tied back through rigid concentric tubulars to the NNM platform and completed with dry trees

- a 26-inch export pipeline, approximately 165 km long, which ties the platform back to the Prelude FLNG facility, and
- subsea integration system connecting the export pipeline system with Crux platform and the Prelude FLNG facility, comprising risers, subsea isolation facilities, pipeline inspection gauge receiver and associated control systems.

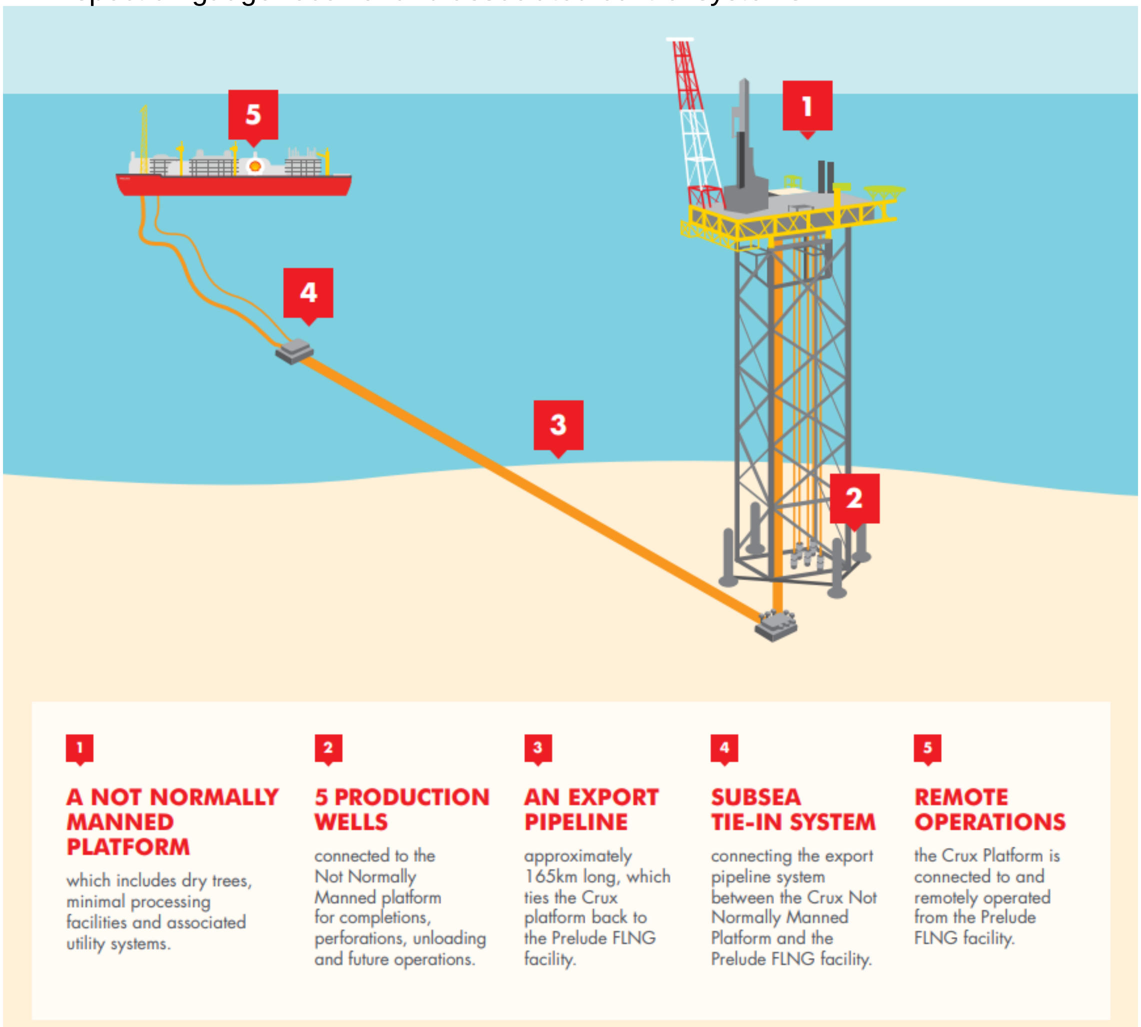



Figure 1-2: Crux Project Concept

A summary of the key project stages and development activities for the Crux project is presented in

**Table** 1-1. Front-End Engineering and Design (FEED) for the project commenced in 2019 with the Financial Investment Decision (FID) currently scheduled to occur in 2020. The project is anticipated to have a 20-year design life. However, subject to future investment decisions, the project may be extended.

Table 1-1: Key Project Stages and Development Activities

| Project Stage | Key Activities |
|---|---|
| Development drilling – including well tie-back to the platform and well completion | • Drilling of production wells<br>• Foundation wells tied-back and completed with dry tree using a Modular Platform Rig (MPR) (or similar completions unit) temporarily installed on the Crux platform<br>• Wells perforated and unloaded with a coiled tubing unit and a temporary test package |
| Installation and hook-up of platform, export pipeline and subsea integration system | • Transport, installation and piling of jacket<br>• Transport and installation of platform topsides<br>• Installation and pre-commissioning (e.g. hydrotesting and dewatering) of export pipeline<br>• Installation of subsea integration system, including Crux pipeline end termination, Prelude pipeline end manifold and risers |
| Commissioning | • Commissioning testing and monitoring topside equipment on the platform and the export pipeline |
| Operations and maintenance | • Well, flowline and riser operations<br>• Remote production and processing operations<br>• Planned maintenance and shutdown campaigns<br>• During operations, additional fields within the in-field development area may be developed. Key activities associated with the development of these fields may include:<br>o Installation and commissioning of subsea facilities to support future subsea tie-backs, and<br>o Installation and commissioning of future compression module |
| Decommissioning | • Well abandonment<br>• Decommissioning of the platform<br>• Decommissioning of subsea facilities and export pipeline |

The in-field development area, as defined in this OPP, incorporates the development of the Crux field and associated gas fields that may be developed as future staged developments within the Crux near field and tied back to the Crux platform.

## 1.2. Development Objectives

The objectives of the proposed project are to:

- commercialise the hydrocarbon resources of the Crux project and optimise recovery of these resources
- manage all environmental, health, security and safety issues in accordance with recognised industry standards and Shell's requirements
- provide an acceptable return on investment, and
- provide for a commercial means to unlock the stranded gas reserves and backfill the Prelude field.

Shell is confident that the project can be developed and operated in an environmentally sustainable manner and that environmental impacts and risks can be managed to an acceptable level.

## 1.3. OPP Purpose and Scope

The impact assessment of the proposed project has been aligned to meet the requirements of an Offshore Project Proposal (OPP) regulated under the Commonwealth Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS (E) Regulations) and administered by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA).

An assessment of the proposed Crux project has been progressed, in accordance with the Shell Health, Security, Safety, Environment and Social Performance (HSSE & SP) Control Framework, to *'identify and assess the potential environmental, social and health impacts of a project, and to implement measures so that negative impacts are minimised, and positive impacts are optimised.'*

The purpose of the OPP is to describe:

- the project area, the proposed activities and its expected timeframe
- the environmental management framework for the proposal, including legislation and other requirements
- the existing natural, social and economic environments of the local and regional setting, including issues or sensitivities particular to the proposal
- the possible impacts and risks to the environment from both planned (normal) and unplanned (emergency) operations
- Shell's Health, Security, Safety and Environment and Social Performance (HSSE & SP) Commitment and Policy and the environmental performance objectives that derive from the Policy, and
- a framework for the forward environmental management and performance, including definition of key management controls and Environmental Performance Outcomes (EPOs), from which environmental performance will be measured and monitored throughout the life of the project.

The OPP is designed as an early stage, whole-of-project assessment. Subject to NOPSEMA's acceptance of the OPP, it will form the basis of future activity-specific Environment Plans (EPs) that will be submitted to NOPSEMA for acceptance as part of subsequent staged development and permitting.

The structure of the OPP and the relevant sections of the OPGGS (E) Regulations are shown in **Table 1-2**. This OPP has been prepared in alignment with current published guidance on OPP content requirements (NOPSEMA 2018a), and related Policy for OPP Assessment (NOPSEMA 2018b).

Table 1-2: OPP Structure, Content and Relationship to the OPGGS (E) Regulations

| OPPGS (E) Regulation | Requirements | Section |
|---|---|---|
| *Regulation 5A Submission of an Offshore Project Proposal* | | |
| 5A (5) (a) | Include the proponent's name and contact details. | Section 1.4 |
| 5A (5) (b) | Include a summary of the project, including the following:<br>(i) a description of each activity that is part of the project;<br>(ii) the location or locations of each activity;<br>(iii) a proposed timetable for carrying out the project;<br>(iv) a description of the facilities that are proposed to be used to undertake each activity; and<br>(v) (v) a description of the actions proposed to be taken, following completion of the project, in relation to those facilities. | Section 5 |
| 5A (5) (c) | Describe the existing environment that may be affected by the project. | Section 6 |
| 5A (5) (d) | Include details of the particular relevant values and sensitivities (if any) of that environment. | Section 6.7 |
| 5A (5) (e) | Set out the environmental performance outcomes for the project. | Section 8,<br>Section 9 |
| **OPPGS (E) Regulation** | **Requirements** | **Section** |

| | | |
|---|---|---|
| 5A (5) (f) | Describe any feasible alternative to the project, or an activity that is part of the project, including:<br>(i) a comparison of the environmental impacts and risks arising from the project or activity and the alternative; and<br>(ii) an explanation, in adequate detail, of why the alternative was not preferred. | Section 5.8 |
| 5A (6) | Requirement to address particular relevant values and sensitivities [as defined in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)]. | Section 6,<br>Section 7,<br>Section 8 |
| 5A (7) | The proposal must:<br>a) describe the requirements, including legislative requirements, that apply to the project and are relevant to the environmental management of the project; and<br>b) describe how those requirements will be met. | Section 2 |
| 5A (8) | The proposal must include:<br>a) details of the environmental impacts and risks for the project; and<br>b) an evaluation of all the impacts and risks, appropriate to the nature and scale of each impact or risk. | Section 8 |
| *Regulation 11A Consultation with relevant authorities, persons and organisations, etc.* | | |
| 11A | Consultation with relevant authorities, persons and organisations.<br><br>[Note while this Regulation relates specifically to consultation required for an EP, the general intent can be applied to an OPP] | Section 4 |

## 1.4. Proponent

The project proponent for the Crux project is Shell Australia Pty Ltd (Shell). The Shell Group of companies is the largest equity LNG producer among international energy companies and has the most diverse LNG supply portfolio in the world. The Shell Group has been in Australia since 1901 and has continued to evolve to meet the changing needs of the Australian and international markets. Today, Shell is focused on the exploration, development and production of Liquefied Natural Gas (LNG), domestic gas and associated products such as liquified petroleum gas (LPG) and condensate. Shell is a major investor in key Australian LNG projects, including the Shell-operated Prelude FLNG Facility.

Shell's Joint Venture Participants for the Crux project are SGH Energy and Osaka Gas. SGH Energy, a subsidiary of SGH, is an Australian oil and gas company with a portfolio of high quality assets and a resources base in the offshore Gippsland Basin in Victoria, and in the Browse Basin in northern WA. Osaka Gas has over 110 years of experience in the energy sector and has grown into a diversified energy company, across the entire natural gas value chain. The Crux Joint Venture Participants bring collective expertise and support for the sustainable commercialisation of the gas fields, in support of backfill to the Prelude FLNG facility.

Contact details for the proponent are:

Shell Australia Pty Ltd

Address: 562 Wellington Street

Perth 6000

Western Australia

Shell Community Hotline:

1800 059 152

https://www.shell.com.au/about-us/projects-and-locations/the-crux-project/crux-community-hotline.html

## 1.5. Organisation of this OPP

This OPP is prefaced by an Executive Summary and the remainder of the document structure is summarised as follows:

- ***Section 1*** provides an overview of the Crux project, summary of Shell's organisational profile, and outlines the purpose and structure of the OPP.
- ***Section 2*** establishes the policy, legal and administrative framework for the Crux project. It provides an overview of the legislation, standards, guidelines and key publications released by the Department of the Environment and Energy (DoEE) that are considered applicable to the Crux project.
- ***Section 3*** describes the management framework and management system that Shell implements to incorporate the commitments made for the Crux project into its daily business and operations.
- ***Section 4*** provides a summary of Shell's approach to stakeholder engagement, as it relates to the Crux project. It describes the engagement methodology and the outcomes of engagement feedback leading up to and including the OPP public comment period, as well as Shell's commitment to maintain open ongoing communication with relevant stakeholders.
- ***Section 5*** describes the Crux project and provides details on the key project phases (from development drilling through to decommissioning) and associated activities within the project area as relevant to the assessment of potential environmental impacts and risks. This section also provides an assessment of the alternative development concepts and activities considered early in the project development process.
- ***Section 6*** provides a detailed description of the key physical, biological, socio-economic and cultural values and sensitivities of the existing environment in which the Crux project will be located. It also provides a summary of the Crux baseline environmental studies undertaken to inform the project.
- ***Section 7*** describes the considerations in defining acceptable levels of impact and risk, in the context of the receiving environment relevant to the Crux project.
- ***Section 8*** provides a detailed evaluation of all impacts and risks associated with the project, from both planned activities and unplanned/emergency events, and from a cumulative impact perspective.
- ***Section 9*** outlines the environmental performance framework for the project, and details Shell's overarching delivery mechanism for implementing the commitments made in the OPP. The section also outlines environmental monitoring that will be undertaken throughout operations.
- ***Section 10*** provides a comprehensive summary of all citations and references of supporting literature relevant to the content of the OPP. A list of acronyms used in this document is also included.

# 2. Policy, Legal and Administrative Framework

## 2.1. Overview

This section provides an overview of the legislation, standards and guidelines which are applicable to the project, including the following:

- Australian policy, legislation and regulations
- relevant international and/or industry policies, guidelines, standards and technical guidance
- relevant provisions contained within international conventions and protocols to which Australia is a signatory, and
- applicable Shell Standards and Guidelines.

## 2.2. Commonwealth Policy Framework

The Crux project is located wholly in Commonwealth waters and is therefore subject to Commonwealth legislation. The following are Commonwealth Government policies regarding petroleum development and marine protection that are relevant to the Crux project.

### 2.2.1 Australian Offshore Petroleum Regime

The Australian Government is responsible for petroleum rights and activities beyond coastal waters (seaward of the first three nautical miles of the territorial sea) to the outer limits of Australia's Exclusive Economic Zone, with title decisions carried out jointly with the relevant regional State or Territory Government (Department of Industry, Innovation and Science (DIIS) 2018).

Onshore and in coastal waters (the first three nautical miles from the coastline), the States and the Northern Territory (NT) allocate petroleum rights, administer petroleum operations and collect royalties on petroleum produced (DIIS 2018). Titles are issued to the private sector by Commonwealth and State Government agencies to facilitate and encourage exploration and development of petroleum reserves within Australia.

### 2.2.2 Commonwealth National Oceans Policy

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

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

Under the Oceans Policy, a Nationally Representative System of Australian Marine Parks (AMPs) has been established. These are based on the principles of multiple-use and Ecologically Sustainable Development (ESD). This policy has been implemented through the EPBC Act, as outlined in the Strategic Plan of Action for the National Representative System of Marine Protected Areas (ANZECC 1998).

The Crux project is not located within any AMPs. The closest AMPs to the Crux project are the Kimberley Marine Park and Cartier Island Marine Park, which are located approximately 95 km south and 100 km north-west of the proposed Crux NNM platform, respectively.

## 2.3 Legislative Framework

This section describes legislation of relevance to the project. Key legislation is described in **Section 2.3.1**, with other relevant legislation outlined in **Section 2.3.2**.

### 2.3.1 Key Legislation

#### 2.3.1.1 *Offshore Petroleum and Greenhouse Gas Storage Act 2006*

In order to provide protection of the environment in Commonwealth waters, the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPPGS Act) ensures that all offshore petroleum and greenhouse gas (GHG) storage activities are undertaken in a manner where impacts and risks on the environment are of an acceptable level and reduced to as low as reasonably practicable (ALARP). This includes risks to Matters of National Environmental Significance (MNES) protected under Part 3 of the EPBC Act. The OPGGS Act requires that all activities are consistent with the principles of ESD, as defined in the EPBC Act (Section 3A):

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

The OPGGS Act and supporting regulations are administered by NOPSEMA. Particularly relevant subordinate regulations of the OPGGS Act are the:

- OPGGS (E) Regulations, which provide further definition and guidance on the environmental management of offshore petroleum and GHG storage activities
- OPGGS (Safety) Regulations, which ensure that facilities are designed, constructed, installed, operated, modified and decommissioned in Commonwealth waters only in accordance with Safety Cases that have been accepted by NOPSEMA, and
- OPGGS (Resource Management and Administration) Regulations, which requires that a Well Operations Management Plan (WOMP) are assessed and accepted by NOPSEMA for existing or proposed offshore facilities.

#### 2.3.1.2 *Environment Protection and Biodiversity Conservation Act 1999*

The EPBC Act and supporting regulations provides for the protection of the environment and conservation of biodiversity in Australia (including Australian waters) by the Commonwealth Government. The EPBC Act is administered by the Commonwealth Minister for the Environment and Energy, with departmental responsibility provided to the DoEE.

Amendments to the OPGGS Act and OPGGS (E) Regulations in February 2014, undertaken as part of the Commonwealth streamlining environmental approvals process, require MNES to be addressed in assessments of offshore petroleum development approvals. Therefore, the OPP process under the OPGGS (E) Regulations supersedes the Commonwealth referral process under the EPBC Act and replaces the requirement to prepare environmental approvals for submission to DoEE for petroleum development activities in Commonwealth waters. As such, this OPP addresses the EPBC Act requirements for the Crux project.

MNES of relevance to the Crux project OPP are discussed in **Section 6**.

### 2.3.2 Other Legislation

A detailed listing of other relevant Commonwealth legislation is outlined in **Table 2-1**.

Table 2-1: Commonwealth Legislation Relevant to the Crux Project

| Commonwealth Legislation/ Regulation | Summary | Relevance to the Project |
|---|---|---|
| *Navigation Act 2012* | The Act regulates and manages health, safety and environmental (HSE) aspects of legislation for marine vessels in Australian waters. It gives effect to the relevant international conventions relating to maritime issues to which Australia is a signatory, such as the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78). The Act also has subordinate legislation contained in Regulations and Marine Orders. | The project will adhere to MARPOL and the various Marine Orders (as appropriate to vessel class) enacted under this Act. |
| *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (POTS Act) and Protection of the Sea (Prevention of Pollution from Ships) (Orders) Regulations 1994 | The Act regulates discharges from ships to protect the sea from pollution. This includes a prohibition against discharges of oil or oily mixtures, noxious liquid substances, packaged harmful substances, sewage and garbage to the sea. The Act imposes a duty to report certain incidents involving prohibited discharges and to maintain record books and management plans.<br><br>The Act also enacts MARPOL 73/78 requirements and implements the Marine Orders. | Vessels within the project area are subject to this Act and will adhere to the requirements for discharges and waste management outlined in the relevant MARPOL and Marine Orders (as appropriate to vessel class).<br>The MARPOL annexes and Marine Orders of relevance to the Crux platform include:<br>• Annex I: Marine Order 91 – Marine pollution prevention – oil<br>• Annex III: Marine Order 94 – Marine pollution prevention – packaged harmful substances<br>• Annex V: Marine Order – Marine pollution prevention – garbage, and<br>• Annex VI: Marine Order 97 – Marine pollution – air pollution. |
| *Fisheries Management Act 1994* and related legislation | The Act defines the Australian Fishing Zone (AFZ) and establishes the legislative basis for management plans for Commonwealth fisheries.<br><br>As a related WA statute, the *Aquatic Resources Management Act 2016*, when it comes into force in January 2019, will become the primary legislation used to manage fishing, aquaculture, pearling and aquatic resources in WA. | The project will be developed with regard to relevant interactions with Commonwealth and State fisheries interests. |

| Commonwealth Legislation/ Regulation | Summary | Relevance to the Project |
|---|---|---|
| *Environmental Protection (Sea Dumping) Act 1981* | This Act provides for the protection of the environment by regulating dumping into the sea, incineration at sea and artificial reef placements. | The project may result in the release of wastes into the sea. Shell recognises the importance of minimising waste disposal to the marine environment and will adhere to the requirements of this Act.<br>This Act may also be relevant in the context of future decommissioning activities, subject to the decommissioning strategy identified at the time. |
| *National Greenhouse and Energy Reporting Act 2007*<br><br>National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 | The Act provides a single, national framework for the reporting and distribution of information related to GHG emissions, GHG projects, energy production and energy consumption. Reporting obligations are imposed upon corporations that meet particular emissions/energy thresholds.<br>The Act includes National Greenhouse and Energy Reporting (NGER) requirements and the safeguard mechanism requirements.<br>The safeguard mechanism provides a framework for the measurement, reporting and management of emissions for facility's whose emissions are > 100,000 t $CO_2$-e<br>The safeguard mechanism applies to direct emissions (scope 1), including direct emissions from energy production.<br>Emissions baselines are set for the facility and provide a reference point against which emissions performance is measured under the safeguard mechanism. A facility's baseline can be adjusted to accommodate economic growth or natural resource variability. If a facility's baseline has, or is likely to exceed, the baseline set, there are a number of options available to manage the excess emissions, such as the purchase and surrender of Australian carbon credit units. | Shell will report as a corporate group under the Act and emissions from the Crux NNM platform will be incorporated into the total emission reporting by Shell, once the project facility becomes operational.<br>The safeguard mechanism will be applied, as relevant to the project context. |
| *Australian Heritage Council Act 2003* | This Act identifies areas of heritage value, including those listed on the World Heritage List, National Heritage List and the Commonwealth Heritage List. | The project will take into consideration any heritage values (see **Section 6.6** for details). |
| *Historic Shipwrecks Act 1976* and Historic Shipwrecks Regulations 1978 | This Act protects shipwrecks and associated relics In Commonwealth waters that are more than 75 years old. The Act aims to ensure that historic shipwrecks are protected for their heritage values and maintained for recreational, scientific and educational purposes. It is an offence to disturb any shipwreck protected under this Act. | Planned project operations will not interfere with any historical shipwrecks (see **Section 6.6.11** for details). |

| Commonwealth Legislation/ Regulation | Summary | Relevance to the Project |
|---|---|---|
| *National Environment Protection Council Act 1994* | This Act establishes the National Environment Protection Council (NEPC). The primary functions of the NEPC are to:<br>define National Environment Protection Measures (NEPMs) to ensure that Australians have equivalent protection from air, water, soil and noise pollution, and<br>assess and report the implementation and effectiveness of NEPMs.<br>This Act is mirrored in all States and Territories. For example, in WA the equivalent Act is the *National Environment Protection Council (Western Australia) Act 1996*. | The project will comply with the requirements of the relevant NEPMs. |
| National Environment Protection (National Pollutant Inventory) Measure 1998 (established under the *National Environment Protection Council Act 1994*) | This measure provides the framework for the development and establishment of the National Pollutant Inventory (NPI), which provides publicly available information on the types and amounts of 93 toxic substances being emitted into the Australian environment. These substances have been identified as important due to their possible effect on human health and the environment.<br>Implementation of the NPI NEPM is the responsibility of each participating jurisdiction. | The project will comply with the NPI NEPM through the reporting of relevant NPI substances. |
| *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* and Regulations 1995 | The Act protects the environment by reducing emissions of ozone depleting substances (ODSs) and synthetic greenhouse gases (SGGs). It controls the manufacture, import and export of ODSs and SGGs and products containing these gases. | The project will adhere to restrictions on import and use of ODSs/SGGs through implementing appropriate measures that control procuring of products which contain these gases. |
| *Biosecurity Act 2015* | The Act and its supporting legislation are the primary legislative means for managing risk of pests and diseases entering Australian territory. The Act includes requirements for pre-arrival reporting, ballast water management plans and certificates. | The project will comply with biosecurity requirements, specifically in relation to biofouling and ballast water requirements. |
| *Hazardous Waste (Regulation of Exports and Imports) Act 1989* | This Act regulates the export, import and transport of hazardous waste to ensure that hazardous waste is managed appropriately so that human health and the environment are protected from the harmful effects of the waste. | The project will comply with the export, import and transport requirements for hazardous waste. |
| *Telecommunications Act 1997* | This Act regulates the telecommunications industry in Australia, including carriers and carriage service providers. | Secondary approvals required for the fibre optic cable (see **Section 5.6.3.4** for details) will consider the requirements of this Act, while noting that the fibre optic cable is not in its own right a petroleum activity under the OPGGS Act and related Regulations. |

| Commonwealth Legislation/ Regulation | Summary | Relevance to the Project |
|---|---|---|
| *Australian Jobs Act 2013* | The Act details Australian industry participation requirements for major projects valued at A$500 million or more. The Act ensures that information about opportunities to bid for work on major projects is provided by all levels of the project's supply chain. | Shell is preparing an Australian Industry Participation Plan for the project. Refer to **Section 2.5** for further details. |

## 2.4 Administrative Framework

This section outlines the additional administrative approvals required under Commonwealth legislation.

### 2.4.1 Production Licence

A petroleum production licence is required for offshore petroleum production facilities under the OPGGS Act. A production licence provides the legal right to recover petroleum from an area, subject to meeting conditions specified by the licence.

### 2.4.2 Infrastructure Licence

An infrastructure licence is required prior to construction or operation of an infrastructure facility in an offshore area under the OPGGS Act. An infrastructure facility includes a facility engaged in petroleum activities that either rests on the seabed or is fixed or connected to the seabed (whether or not the facility is floating).

Shell has not yet applied for an infrastructure licence. The infrastructure licence will be issued by the National Offshore Petroleum Titles Administrator (NOPTA).

### 2.4.3 Pipeline Licence

A pipeline licence is required for the construction and operation of offshore pipelines, such as the export pipeline, under the OPGGS Act. As per the infrastructure licence, the pipeline licence will be issued by NOPTA.

### 2.4.4 Environment Plans

Under the OPGGS (E) Regulations, the titleholder is required to submit an EP before commencing an activity and the activity cannot take place until NOPSEMA accepts the EP. EPs must describe the activity, the receiving environment, and provide a detailed evaluation of environmental impacts and risks associated with the activity. The EP is also required to outline appropriate performance outcomes (i.e. EPOs), performance standards and measurement criteria for determining whether the outcomes and standards are met. In addition, an implementation strategy is provided to demonstrate how the impacts and risks will be managed to ALARP and acceptable levels, how performance outcomes and standards are met, and detail the arrangements in place to respond to and monitor oil pollution emergencies.

A series of EPs will be developed by Shell for specific activities throughout the project life-cycle.

Under the OPGGS (E) Regulations, an Oil Pollution Emergency Plan (OPEP) is required as part of the implementation strategy for the activity-specific EP. The OPEP must include comprehensive and adaptable arrangements for responding to and monitoring oil pollution. The OPEP will be supported by an Operational and Scientific Monitoring Program (OSMP) that provides a detailed strategy for responding to large-scale releases to the marine environment.

### 2.4.5 Safety Case and Well Operations Management Plan

As mentioned in **Section 2.3.1.1**, the OPGGS (Safety) Regulations and OPGGS (Resource Management and Administration) Regulations also require that a Safety Case and a WOMP are assessed and accepted by NOPSEMA for existing or proposed facilities.

Shell will prepare and submit the required Safety Cases to NOPSEMA as the Crux project is developed to ensure timely approvals prior to construction, installation and start-up. A WOMP will be developed for all activities in the life of the well. These approvals assist in environmental protection as they ensure the integrity of the production wells throughout their life, drilling rig, Crux platform and project vessels.

## 2.5 Australian Industry Participation Plan

An Australian Industry Participation (AIP) Plan is a requirement of the *Australian Jobs Act 2013*. The requirement for an AIP Plan is triggered by any major construction project of over $500 million investment. The overarching aim of the Plan is to ensure investment and project delivery is contained within Australia; and that offshore spend is limited as much as possible.

The key objective of the Act is to ensure Australian entities have full, fair and reasonable opportunity to bid for the supply of key goods or services for the project and, if applicable, the initial operations of the facility.

The AIP Plan assists Shell in achieving this objective.

It is a requirement of the Act that an AIP Plan is lodged before detailed design and major procurement decisions are undertaken. In June 2018, Shell notified the AIP Authority that it will submit an AIP Plan for the Crux project in Q4 2018. Approval for the AIP Plan was obtained in Q4 2018.

## 2.6 Relevant State/Territory Legislation

The Crux project, including its associated infrastructure and planned operations, is located in Commonwealth waters. Some planned activities, such as vessel transfers, and unplanned activities, however, have the potential to interact with values and sensitivities within both the jurisdiction of WA and NT (refer to **Section 6** for discussion of sensitivities). Onshore support facilities required during construction, commissioning and operation will be located in existing ports and associated industrial areas.

Any future supporting activities for the Crux project in State/Territory jurisdiction will be undertaken in accordance with relevant State/Territory legislation prevailing at the time.

## 2.7 Industry Good Practice Standards

In addition to the offshore environmental management procedures and reporting required under legislation, there are voluntary industry codes that are relevant to the project, as discussed in this section.

In Australia, the petroleum exploration and production industry operates within an industry code of environmental practice developed by the Australian Petroleum Production and Exploration Association (APPEA) (APPEA 2008). This code provides guidelines for activities and has evolved from the collective knowledge and experience of the oil and gas industry both nationally and internationally. The code also provides the Australian petroleum industry with clear guidance on management practices and measures to protect the environment during exploration, production and decommissioning phases. Shell is a signatory to the APPEA guidelines and will align with their intent in the implementation of the project.

The following Australian guidelines are also applicable to the project:

- National Biofouling Management Guidance for the Petroleum Production and Exploration Industry 2009 (Commonwealth of Australia 2009a)
- Australian Offshore Support Vessel Code of Safe Working Practice (Australian Maritime Safety Authority (AMSA) 1997)
- Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities (AMSA 2015a)
- Advisory Note for Offshore Petroleum Industry Consultation with Respect of Oil Spill Contingency Plans (AMSA 2017), and the corresponding WA Offshore Petroleum Industry Guidance Note – Marine Oil Pollution: Response and Consultation Arrangements (Department of Transport (DoT) 2017), and
- Australian Ballast Water Management Requirements (Department of Agriculture and Water Resources (DAWR) 2017).

The following international guidelines are also applicable to the project:

- Improving Social and Environmental Performance: Good Practice Guidance for the Oil and Gas Industry 2017 International Petroleum Industry Environmental Conservation Association (IPIECA 2017)
- The Oil and Gas Industry: Operating in Sensitive Environments 2003 (IPIECA 2003), and
- Environmental Management in Oil and Gas Exploration and Production 1997 – United Nations Environment Program Industry and Environment (UNEP IE) and the Oil Industry International Exploration and Production Forum.

## 2.8 International Standards and Guidelines

Shell refers to World Bank (WB)/International Finance Corporation (IFC) guidelines as the basis for many of its operation guidelines, as aligned with the Shell HSSE & SP Control Framework. The WB/IFC guidelines are the minimum environmental, social and health standards for WB funded projects, unless the standards of the host country are more stringent. Shell will adhere to Australian legislation and guidelines in the first instance unless international standards are more stringent.

The WB/IFC guidelines of primary relevance to the project include:

- IFC Performance Standards on Environmental and Social Sustainability (2012)
- General Environmental, Health, and Safety (EHS) Guidelines (2007, currently under review, with progressive updates expected in 2018-2019) – to provide general guidance on Good International Industry Practice, and
- EHS Guidelines for Offshore Oil and Gas Development (2015).

## 2.9 International Agreements and Conventions

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth Government to prevent pollution and protect specified habitats, flora and fauna. A number of these conventions are specifically designed to protect MNES, including:

- Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention), which aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.
- Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment 1974

(commonly referred to as JAMBA), which recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan.

- Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment 1986 (commonly referred to as CAMBA), which recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China.
- Agreement between the Government of Australia and the Government of the Republic for Korea for the Protection of Migratory Birds and their Environment 2002 (commonly referred to as ROKAMBA), which recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Korea.
- International Convention on Wetlands of International Importance (Ramsar), which encourages the designation of sites containing representative rare or unique wetlands, or wetlands that are important for conserving biological diversity and their management for conservation purposes.
- The Minamata Convention on Mercury requires Parties to address mercury throughout its lifecycle, including its production, its intentional use in products and processes, its unintentional release from industrial activity, though to end-of-life aspects including waste, contaminated sites, and long-term storage. The Convention entered into force on 16 August 2017. Australia is a signatory to the Minamata Convention, however has yet to ratify.

## 2.10 EPBC Management Plans, Recovery Plans, Conservation Advices and Related Guidance

### 2.10.1 EPBC Management Plans, Recovery Plans and Conservation Advices

Under the streamlining arrangements for the assessment of petroleum proposals in Commonwealth waters under the OPGGS (E) Regulations, this requires explicit consideration of MNES protected under Part 3 of the EPBC Act.

The requirements of the relevant species management/recovery plans and conservation advices have been considered to identify any requirements that may be applicable. Recovery plans are enacted under the EPBC Act and remain in force until the species is removed from the threatened list. Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. Conservation advices provide guidance on immediate recovery and threat abatement activities that can be undertaken to facilitate the conservation of a listed species or ecological community.

The management/recovery plans and conservation advices relevant to those species identified as potentially occurring or having habitat within the Crux project area and area of influence (i.e. the existing environment that may be affected from unplanned events) are further detailed in the applicable sections within **Section 6** as part of the description of the existing environment. Relevant management measures from these plans are also considered in relevant parts of **Section 8** as they apply to the project. The management/recovery plans and conservation advices have been taken into consideration in assessing the impacts and risks associated with the project, to demonstrate alignment with the EPBC publications, and will be further incorporated into implementation planning as the project progresses.

### 2.10.2 Related EPBC Guidance

In addition to the relevant specific management/recovery plans and conservation advices specific to MNES, DoEE also has a suite of Policy Statements and related guidance under the EPBC Act.

Of specific relevance to this proposal, particular consideration is given to the following:

- Matters of National Environmental Significance - Significant Impact Guidelines 1.1 published by the DoEE (DoE 2013a). These have been used to inform the definition of acceptability of impacts, and are described in further detail in **Section 7**, and carried into the subsequent evaluation of impacts and risks in **Section 8**.
- EPBC Act Policy Statement ‘Indirect consequences’ of an action: Section 527E of the EPBC Act (Department of Sustainability, Environment, Water, Population and Communities ((DSEWPaC) 2013a). This has been consideration in the specific context of indirect consequences of a proposal with regard to atmospheric emissions, and is addressed in **Section 5.7.5**.

# 3. Shell Health, Security, Safety, Environment and Social Performance Management Framework

## 3.1 Introduction

The Shell Group operates under a common set of business principles, supported by policies, standards and business controls which are implemented throughout the organisation structure. In support of the business principles, there is a Group Health, Security, Safety, Environment and Social Performance Policy which requires every Shell Company to manage HSSE and SP in a systematic manner.

The HSSE and SP Control Framework is a corporate management framework which applies to every Shell Group company, contractor and joint venture under Shell's operational control.

## 3.2 HSSE & SP Policy

The Shell Commitment and Policy on HSSE & SP applies across the Shell Group and is designed to protect people and the environment. The policy, endorsed and adopted by Shell, is presented in **Figure 3-1**. The policy illustrates the commitment made by the senior management and all staff of Shell to achieve not only compliance with environmental standards set by the Australian Government and the Company, but also to seek continual improvements in performance.

Key features of the policy are:

- systematic approach to HSSE and SP management designed to ensure compliance with the law and to achieve continuous performance improvement
- targets for improvement and measurement, appraisal and performance reporting
- requirement for contractors to manage HSSE and SP in line with this policy, and
- effective engagement with neighbours and impacted communities.

# SHELL COMMITMENT AND POLICY ON HEALTH, SECURITY, SAFETY, THE ENVIRONMENT AND SOCIAL PERFORMANCE

## COMMITMENT

**In Shell we are all committed to:**

- Pursue the goal of no harm to people;
- Protect the environment;
- Use material and energy efficiently to provide our products and services;
- Respect our neighbours and contribute to the societies in which we operate;
- Develop energy resources, products and services consistent with these aims;
- Publicly report on our performance;
- Play a leading role in promoting best practice in our industries;
- Manage HSSE & SP matters as any other critical business activity; and
- Promote a culture in which all Shell employees share this commitment.

In this way we aim to have an HSSE & SP performance we can be proud of, to earn the confidence of customers, shareholders and society at large, to be a good neighbour and to contribute to sustainable development.

## POLICY

**Every Shell Company:**

- Has a systematic approach to HSSE & SP management designed to ensure compliance with the law and to achieve continuous performance improvement;
- Sets targets for improvement and measures, appraises and reports performance;
- Requires contractors to manage HSSE & SP in line with this policy;
- Requires joint ventures under its operational control to apply this policy, and uses its influence to promote it in its other ventures;
- Engages effectively with neighbours and impacted communities; and
- Includes HSSE & SP performance in the appraisal of staff and rewards accordingly.

**Ben van Beurden**
Chief Executive Officer

**Zoe Yujnovich**
EVP Australia and New Zealand

Originally published in March 1997 and updated by the Executive Committee December 2009.

General Disclaimer: The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this Policy the expression "Shell" is sometimes used for convenience where references are made to companies within the Shell group or to the group in general. Likewise, the words "we", "us" and "our" are also used to refer to Shell companies in general or those who work for them. These expressions are also used where no useful purpose is served by identifying specific companies.

Figure 3-1: Shell Australia's HSSE & SP Policy

## 3.3 HSSE & SP Control Framework

All Shell's operations are conducted in accordance with Shell's HSSE & SP Control Framework, a comprehensive corporate management framework. This Framework defines a set of mandatory requirements that define minimum HSSE & SP principles and expectations, which are documented in a set of manuals. **Figure 3-2** outlines the various control framework manuals applicable to the Crux project.

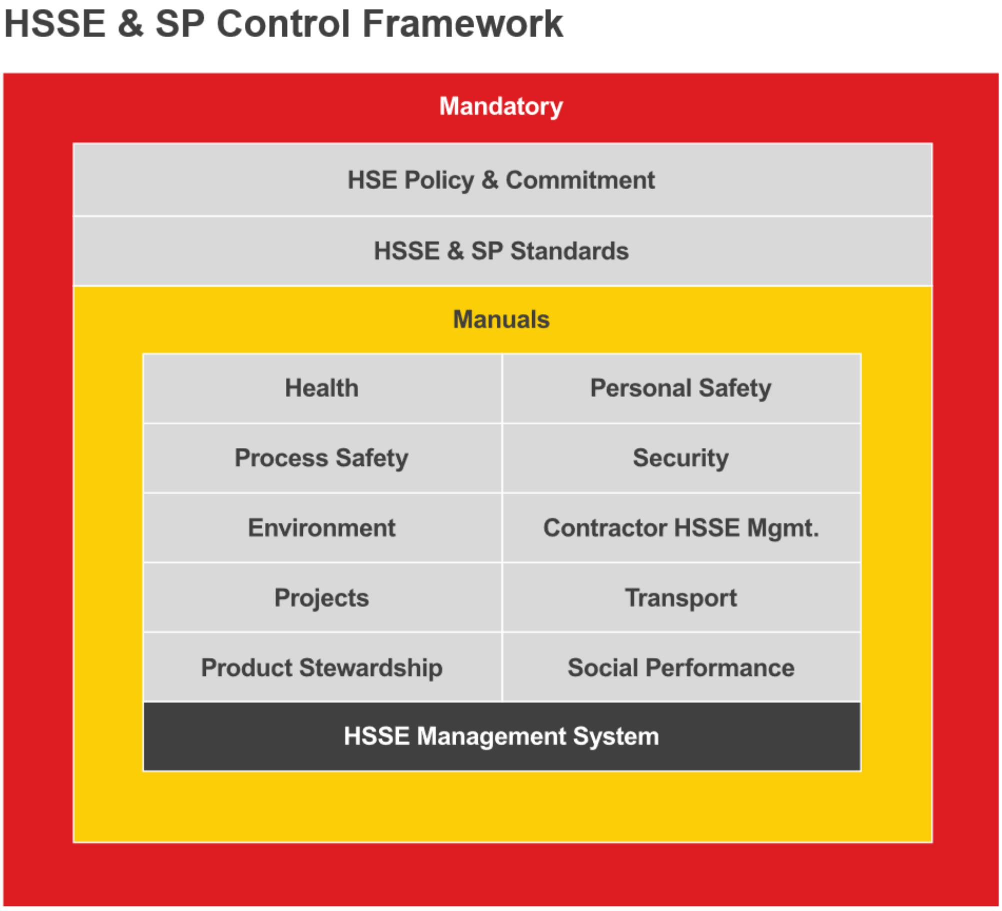



Figure 3-2: Shell HSSE & SP Control Framework

*HSSE & SP Management System*

The Shell Australia HSSE &SP-MS provides a structured and documented framework for the effective management of HSSE & SP risks and demonstrates how the requirements of the Shell Group HSSE & SP Control Framework are implemented throughout Shell. The Shell Australia HSSE & SP-MS Manual consists of the following sections:

- Leadership and Commitment
- Policy and Objectives
- Organisation, Responsibility and Resources, Standard and Documents
- Risk Management
- Planning and Procedures
- Implementation, Monitoring and Reporting
- Assurance, and
- Management Review.

The HSSE & SP-MS is subject to a continuous improvement 'plan, do, check, review' loop, with eight components as outlined in **Table 3-1**. There are numerous, specific ongoing (typically annual) assurance activities against each of the eight components in this HSSE & SP-MS Manual as detailed below. The audit and review function of the HSSE-MS seeks to ensure that the system is being implemented, is effective and to identify areas for improvement. Examples of elements that demonstrate continuous improvement are highlighted under each section.

Table 3-1: HSSE & SP-MS Elements, Implementation and Improvement

| Management System Element | Implementation and Improvement |
|---|---|
| **Leadership and Commitment**<br>*Creating and sustaining a culture that drives Shell's commitment of no harm to people or the environment* | Seek ongoing feedback on how others perceive HSSE & SP leadership (performance reviews, HSE Culture Survey (Shell People Survey), 360 feedback). |
| **Policy and Objectives**<br>*Supporting the implementation of Shell HSSE & SP Commitment and policy* | Set annual HSSE & SP targets to drive continuous performance.<br>Annually review and approve HSSE & SP objectives. |
| **Organisation, Responsibilities and Resources**<br>*Establishing and maintaining an organisation that enables the compliance with the HSSE & SP Control Framework* | When there are changes in the business or organisation, identify the positions that require competence assurance.<br>HSSE & SP Critical Position Register, Shell People Competency Profiles. |
| **Risk Management**<br>*Identifying the HSSE & SP hazards and establishing the controls to reduce the risks to ALARP* | Ongoing review of hazards and risks. Regular review of risk registers. |
| **Planning and Procedures**<br>*To integrate the requirements of the HSSE & SP Control Framework into business plan and procedures: Emergency & Crisis Response, Spill Preparedness and Response, Management of Change, Permit to Work* | Establish and maintain a programme of testing of emergency response plans and procedures at least once a year or more frequently based on the level of risk. Shell Australia Emergency Response Plan, records of emergency response drills, exercises and After Action Reports. |
| **Implementation, Monitoring and Reporting**<br>*Implement the HSSE & SP requirements embedded in plans and procedures and take corrective action when necessary* | Report all Incidents, including near misses, to the supervisor of the work activity. Learn from significant incidents and high potential incidents through communication and implementation of required actions. |
| **Assurance**<br>*Providing assurance that the HSSE & SP Control Framework requirements are implemented and effective* | Establish, maintain and execute HSSE & SP Self-Assessments in support of the Business HSSE & SP Assurance Plan, self-assessment, Control Framework Gap Analysis, HSSE & SP Management Review.<br>Management Review – documents demonstrating how Shell Australia reviews the effectiveness, adequacy and fitness for purpose of the HSSE & SP Management System and acts to improve.<br>Review the HSSE & SP-MS and its individual elements at least once a year and document the results. |
| **Management Review**<br>*Reviewing the effectiveness, adequacy and fitness for purpose of the HSSE & SP-MS and taking actions for improvement* | Assess the effectiveness and adequacy of the management system in delivering the policy and objectives and in driving continual improvement. |

Shell Australia's HSSE & SP-MS covers all operations within its business, including the planning, development and operations of the Crux platform.

Management of HSSE for the Crux project is through the implementation of the Shell Australia HSSE & SP-MS, supplemented by facility/asset specific HSSE systems/procedures (e.g. Shell Permit to Work system and associated procedures such as Confined Space Entry, Isolations, etc. as appropriately developed at the stage of project implementation).

Shell implements specific pre- and post-contract award processes and activities aimed at ensuring that contracts consistently and effectively cover the management of HSSE & SP risks and deliver effective management of HSSE & SP risks for contracted activities. Contractor HSSE & SP Management is governed by the Shell HSSE & SP Control Framework.

As a minimum, all relevant field active contractors' HSSE & SP-MS will be assessed to ensure they meet materially equivalent outcomes to Shell Australia's HSSE & SP-MS.

# 4 Stakeholder Consultation

## 4.1 Introduction

Stakeholder engagement and consultation is an integral part of Shell's social performance, impact assessment and project development process, helping to both inform business decisions and identify issues that require action. Shell has internal policies and processes which outline the requirements of stakeholder engagement. These are underpinned by Shell's General Business Principles (**Section 4.2**), which govern how the Shell companies that make up the Shell Group conduct their affairs.

Stakeholder engagement is a systematic process, starting with developing an understanding of the issues, identifying stakeholders, developing a Stakeholder Engagement Plan and then creating and maintaining stakeholder relationships and partnerships using a variety of engagement methods. Stakeholder engagement is seen as a two-way process, designed to ensure stakeholders can understand, absorb, respond and interact with sufficient information within appropriate timeframes.

Shell is committed to:

- inform stakeholders of the proposed Crux project
- maximise the level of accurate and accessible information about the project
- provide stakeholders with the opportunity to engage in meaningful dialogue
- listen to feedback from stakeholders and respond to them honestly and responsibly
- use stakeholder feedback to inform and improve business decisions, and
- deliver a net benefit to local communities.

A wide range of stakeholders have been identified for the project, comprising individuals and organisations from stakeholder groups including Federal government, State government, non-government organisations, industry and the local community.

Consultation with the Crux project's identified stakeholders will continue throughout the project's lifespan, ensuring that queries and concerns raised are addressed and, where feasible, appropriate responses are built into the design and/or future activity-specific EPs.

## 4.2 Shell General Business Principles and Stakeholder Engagement

Shell's consultation with stakeholders is undertaken in line with the Shell General Business Principles. Key to these principles is that Shell employees share a set of core values – honesty, integrity and respect for people. Key principles for stakeholder engagement:

- Local communities – Shell aims to be a good neighbour by continuously improving the ways in which we contribute directly or indirectly to the general wellbeing of the communities within which we work. We manage the social impacts of our business activities carefully and work with others to enhance the benefits to local communities, and to mitigate any negative impacts from our activities. In addition, Shell companies take a constructive interest in societal matters, directly or indirectly related to our business.
- Communication and engagement – Shell recognises that regular dialogue and engagement with our stakeholders is essential. In our interactions with local communities, we seek to listen and respond to them honestly and responsibly. Part of this commitment is ensuring those people and organisations that are impacted by our activities are engaged, and that their concerns are heard and responded to.

### 4.2.1 Stakeholder Engagement Process

In supporting Shell's adherence to the Shell Business Principles, from the initial discovery of the resource, is a comprehensive stakeholder strategy which ensures that:

- the external context is monitored and understood
- stakeholder needs, interests, concerns and expectations understood, and shared outcomes defined
- a clear and direct link between impacts and risks/opportunities and stakeholders
- stakeholder engagement protocols established and consistent, and
- explicit inclusion of external perspectives in business decisions.

### 4.2.2 Crux Stakeholder Engagement Plan

A Stakeholder Engagement Plan specific to the Crux project has been developed and includes a stakeholder matrix, an engagement strategy and a feedback mechanism.

Shell's approach to stakeholder engagement on the Crux project, as is the case for all of Shell's assets, has always been "a no surprises approach" which has driven proactive engagements with a range of stakeholders from a very early stage. Shell has developed long term working relationships with those who may be impacted by the Crux project or who may have an interest in it.

### 4.2.3 OPP Consultation Strategy

The Crux Stakeholder Engagement Plan, as well as information gathered from ongoing engagement historically undertaken for the Prelude FLNG project, was used to develop an OPP consultation strategy.

Subject matter experts were engaged as required throughout the process, to inform the development of the plan and ensure that Shell staff undertaking consultation have an integrated understanding of the Crux environmental risks and mitigations.

#### 4.2.3.1 Stakeholder Identification

Shell has an internal process to identify, prioritise and understand stakeholders. The process includes the following steps:

1. Identify stakeholders against specific business objectives
2. Prioritise stakeholders based on stakeholder views/concerns
3. Analyse value drivers and views on our activities
4. Define desired shared outcomes
5. Early engagements with stakeholders to understand views of impacts, risks and opportunities.

This process was used to develop the Crux Stakeholder Matrix and formed the foundation for the Stakeholder Identification Workshop. The workshop was held in February 2018 and was attended by External and Government Relations representatives as well as Shell Health, Safety and Environment subject matter experts.

At the workshop, each potential stakeholder was assessed based on how the proposed Crux project activities could impact their functions, interests or activity.

The workshop was informed by:

- historic information gathered as part of the Shell Prelude stakeholder engagement process, and
- desktop research to identify the specific functions, interests and activities of each relevant person.

Once stakeholders were identified, Shell determined the most appropriate consultation approach and associated information to communicate based on the:

- functions, interests and activities of the person
- prior feedback and information from relevant persons on their perspectives and how they prefer to be engaged gathered as part of the Crux stakeholder engagement process, and
- information gathered during prior engagement activities and/or ongoing communication with stakeholders.

#### 4.2.3.2 Stakeholders and Consultation

Stakeholders identified consist of pre-existing stakeholders, engaged through the Prelude FLNG project, as well as others identified through initial engagements with Government agencies, desktop research and regional contacts. The stakeholders can be broadly grouped as follows:

- Federal Government
- State Government
- community (individuals or groups)
- local indigenous representative groups and Traditional Owners
- commercial fishing operators
- local government organisations
- non-government organisations
- industry representative organisations
- tourist operators and tourists, and
- academia.

**Table 4-1** presents a summary of all the stakeholders that have been consulted to date by Shell.

Table 4-1: Crux Project Stakeholders

| Stakeholder Group | Stakeholder |
|---|---|
| Primary Regulatory Bodies | National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA)<br>National Offshore Petroleum Titles Administrator (NOPTA) |
| Commonwealth Government | Australian Border Force (Department of Immigration and Border Protection)<br>Clean Energy Regulator<br>Commonwealth Department of Industry, Innovation and Science (DIIS)<br>Department of Agriculture and Water Resources<br>Department of the Environment and Energy (DoEE)<br>Department of Communications<br>Parks Australia<br>RAN Australian Hydrographic Service<br>Australian Fisheries Management Authority (AFMA)<br>Australian Marine Safety Authority (AMSA)<br>Federal Member for Kimberley |
| State/Territory Government | Department of Mines, Industry Regulation and Safety (DMIRS)<br>Department of Primary Industries and Regional Development (DPIRD) – Fisheries Division<br>Department of Jobs, Tourism, Science and Innovation (formerly Department of State Development)<br>Department of Water and Environmental Regulation (DWER)<br>Department of Biodiversity, Conservation and Attractions (DBCA)<br>Department of Transport (DoT)<br>NT Department of Fisheries<br>Department of Fire and Emergency Services (DFES)<br>Office of Emergency Management (as a sub-department of DFES)<br>State Member for Kimberley |
| Marine Organisations | Australian Institute of Marine Science (AIMS)<br>Australian Marine Oil Spill Centre (AMOSC) |
| Fisheries and Representative Organisations | Commonwealth Fishing Association<br>Kimberley Professional Fishermen’s Association<br>Mackerel Managed Fishery<br>North Coast Shark Fishery<br>North West Slope Fishery<br>Northern Demersal Scalefish Fishery (represented by the Kimberley Professional Fishermen's Association)<br>Pearl Oyster Fishery (represented by Pearl Producers Association)<br>Pearl Producers Association<br>RecFish West<br>Southern Bluefin Tuna Fishery<br>WA Fishing Industry Council (WAFIC)<br>West Coast Deep Sea Fishery<br>Western Tuna and Billfish Fishery |
| Community/Contractor | Australian Broadcasting Corporation<br>Broome Advertiser<br>Broome International Airport<br>Broome Port Authority<br>Broome Visitors Centre<br>Cable Beach Club<br>Canadian Helicopter Company<br>Djarindjin Aboriginal Corporation (DAC)<br>Goolarabooloo Aboriginal Corporation<br>Goolarri Media<br>GWN7 Broome |

| Stakeholder Group | Stakeholder |
|---|---|
| | [redacted]<br>Kimberley Development Commission<br>Kimberley Institute<br>Kimberley Land Council<br>Kimberley Police<br>Lombadina Aboriginal Corporation<br>Maximus Pearls<br>Nirrumbuck Aboriginal Corporation<br>North West Tourism Board<br>Nugurrara Rangers<br>Nyamba Buru Yawuru<br>One Arm Point Aboriginal Corporation<br>Qantas<br>Roebuck Bay Working Group<br>Shire of Broome<br>Toll Energy<br>Wunan<br>Bardi Jawi Prescribed Corporate Body<br>Broome Chamber of Commerce<br>Dambimangarri Aboriginal Corporation |
| Environmental Non-Government Organisations | Australian Conservation Foundation<br>Australian Marine Conservation Society<br>Conservation Council of WA<br>Environmental Defenders Office WA<br>Greenpeace<br>Save the Kimberley<br>Wilderness Society<br>World Wildlife Fund |

### 4.2.4 Early Consultation

As part of Shell's commitment to early engagement, a Crux project website has been established and initial factsheets published, providing an overview of the project and the OPP process. The Crux project website is located at:

https://www.shell.com.au/about-us/projects-and-locations/the-crux-project.html

Shell held an industry briefing in June 2018, which was attended by representatives from Commonwealth Government (including NOPSEMA and NOPTA), State Government (including DPIRD – Fisheries; Department of Jobs, Tourism, Science and Innovation; and Department of Industry, Department of Commerce), marine organisations (including AIMS), and representative industry bodies (including APPEA, Chamber of Minerals and Energy, and AMOSC). In a follow-up to the briefing, Shell has commenced targeted engagement with a range of relevant stakeholders, including Government agencies, commercial fishing associations and other interested stakeholders, to discuss the project's status and facilitate the opportunity for feedback.

### 4.2.5 OPP Public Consultation

A core element of the OPP process is to facilitate a public comment period. The OPP was published on NOPSEMA's website and made available on Shell's website. The length of the public comment period is subject to determination by NOPSEMA, ranging from 4 to 12 weeks duration. NOPSEMA has published guidance information to support this public comment engagement process (NOPSEMA 2018c). For the Crux project, the OPP was released for a six week public comment period from 4 February 2019 to 18 March 2019.

The outcomes of consultation will be planned, tracked and recorded as part of the Crux Stakeholder Engagement Plan, supported by an Action Register to support the tracking of committed actions.

### 4.2.6 Ongoing Consultation

Upon acceptance of the OPP, Shell will uphold its commitments to ensuring relevant persons continue to be consulted throughout the development of the Crux project.

Shell has determined that the most effective way to manage ongoing consultation in line with the OPP and subsequent activity-specific EPs will be undertaking consultation around the key project milestones of installation, commissioning, start up and operations. Consultations will be tailored to the specific functions, interests or activities of the stakeholders relevant to the stage of the project.

The assessment is dynamic and could change, for example changes to scope or schedule, in which case the plan would be updated. As each key project milestone is reached, an assessment will occur to ensure that all relevant persons are engaged appropriately.

Stakeholders can and have identified their preferred ongoing engagements for the Crux project. In such cases, that suggestion is considered and if appropriate, implemented.

These consultations will be planned, tracked and recorded as part of the Crux Stakeholder Engagement Plan.

Shell's 'management of change' process will also ensure that any material changes to the activity scope will trigger engagement with those who may be impacted, with periodic internal compliance/assurance checks in place in line with good industry practice.
Shell will ensure any claims or objections, or feedback, from the ongoing consultation is processed as per Shell's internal claims process, and any required follow-up action will be managed appropriately.

# 5 Description of the Project and Alternatives Analysis

## 5.1 Overview

This section of the OPP provides a comprehensive description of the key stages and activities associated with the development and operation of the Crux project, as relevant to the assessment of environmental impacts and risks, such as the key discharge and emission sources. It defines the nature and scale of the Crux project to facilitate an appropriate description of the existing marine environment (**Section 6**). Understanding both the project and the existing marine environment allows the sources of impacts and risks to be appropriately evaluated (**Section 7**).

## 5.2 Project Concept and Design

The Crux project has been identified as the primary source of backfill gas supply to the Prelude FLNG facility. The Crux project will not increase the production capacity of the Prelude FLNG facility. The scope of the existing Prelude FLNG facility environmental approvals include backfill projects. The current project concept is shown in **Figure 5-1** and comprises:

- a NNM platform, which includes dry trees, processing facilities and associated utility systems
- five production wells with subsea wellhead system tied back through rigid concentric tubulars to the NNM platform and completed with dry trees
- a 26-inch export pipeline, approximately 165 km long, which ties the platform back to the Prelude FLNG facility, and
- subsea integration system connecting the export pipeline system with Crux platform and the Prelude FLNG facility, comprising risers, subsea isolation facilities and associated control systems.

There is also a potential for future subsea developments that will provide hydrocarbons to the Crux platform. These developments are expected to comprise subsea production wells, completed with subsea trees, and associated subsea tie-back to the platform (e.g. flowlines, risers and manifolds).

Shell have undertaken concept engineering to support the selection of these facilities. During this process, all reasonable alternative development options/activities were considered in order to fully evaluate the environmental acceptability of the project.

A high-level evaluation and comparison of environmental impacts and risks for key development option/activity alternatives is discussed in **Section 5.8**.

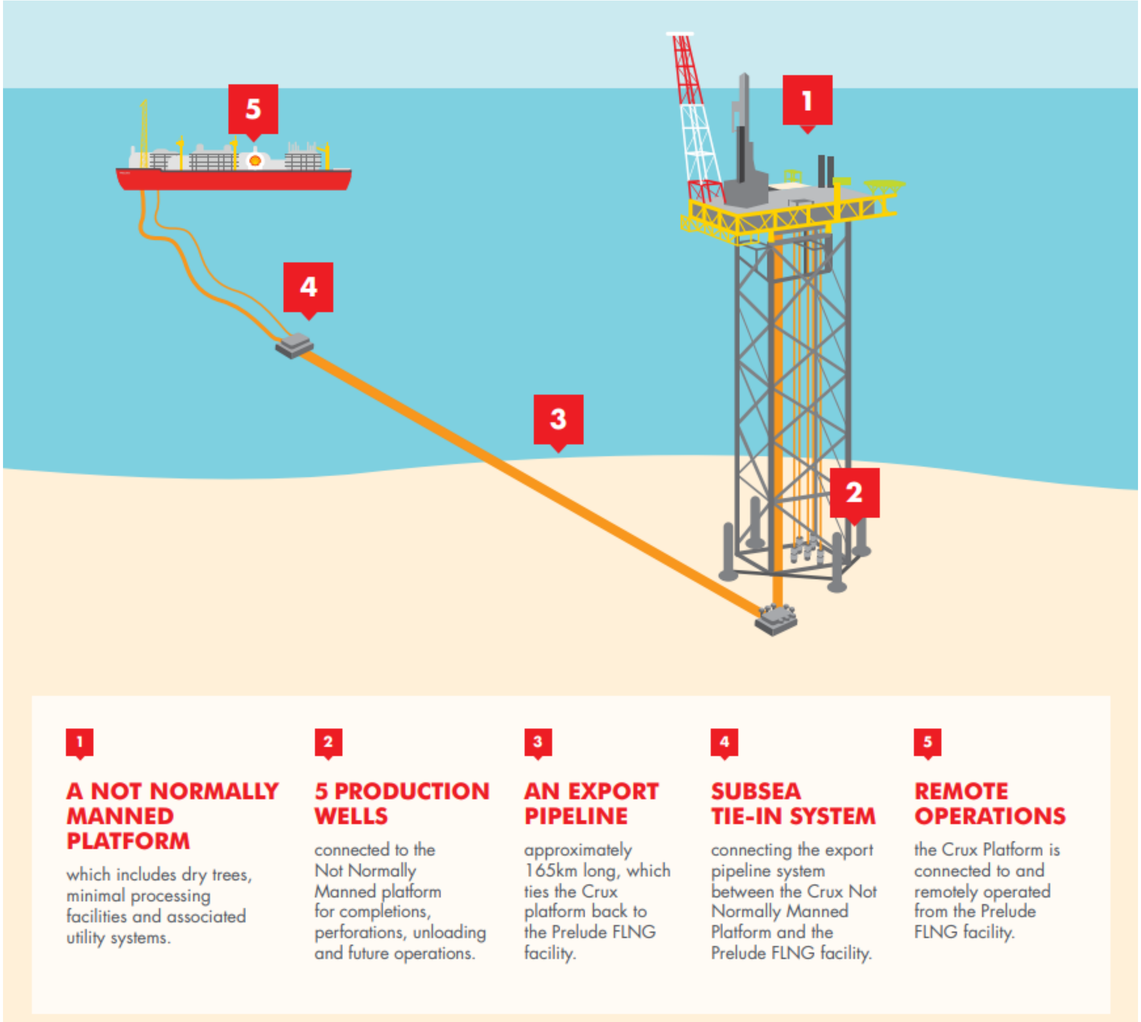



Figure 5-1: Concept Schematic of the Crux Project

## 5.3 Project Location

The Crux project is located in the northern Browse Basin in offshore Commonwealth marine waters approximately 160 km offshore north-west Australia and 620 km north-north-east of Broome, the nearest regional centre. The location of the Crux project is presented in **Figure 5-2**.

The proposed export pipeline spans between the Crux platform and the Prelude FLNG facility in Commonwealth marine waters. The pipeline is approximately 190 km offshore north-west Australia at its closest point and water depths range from approximately 170 m to 280 m.

The Crux project area (as defined in **Section 5.3.1**) does not contain any emergent reefs/islands. The nearest reef/island to the Crux platform is Cartier Island, which is approximately 105 km to the north-west. The nearest shoal/bank is Goeree Shoal, which is approximately 13 km to the north-west of the Crux platform location.

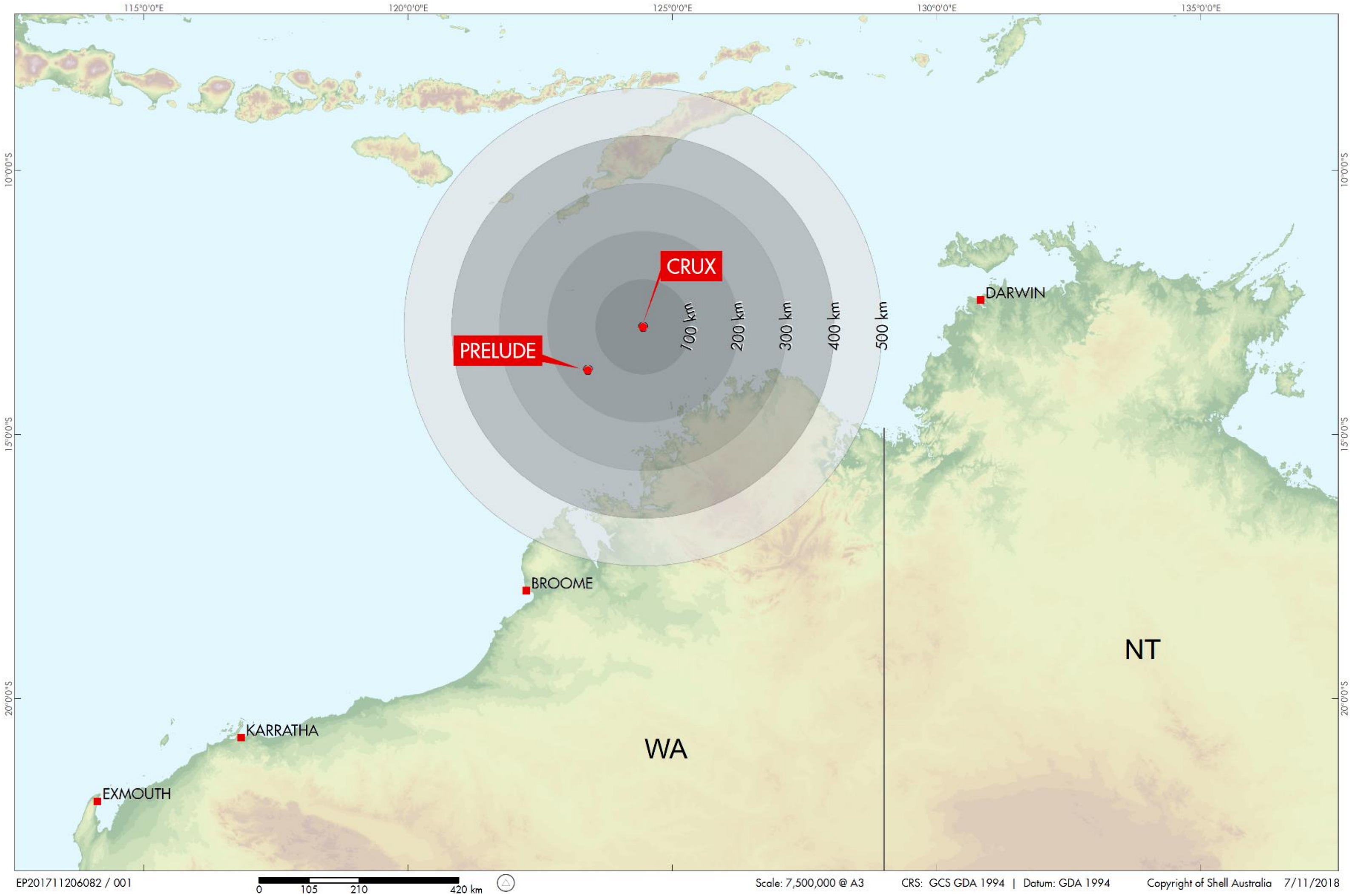



Figure 5-2: Crux Project Location

### 5.3.1 Project Area Definition

The Crux in-field development area and export pipeline corridor define the geographic extent of the project area that is applicable for planned activities, which are considered and risk assessed in this OPP. For the purposes of this OPP, the extent of the in-field development area and export pipeline corridor (collectively referred to as the 'project area') is considered to comprise the area outlined in **Figure 5-3** and **Figure 5-4**, respectively.

The in-field development area incorporates the development of the Crux field and associated gas fields that may be developed as future staged developments within the Crux near field. The outer radius of potential backfills from the proposed Crux platform location will be 30 km from the current proposed platform location, excluding a 1 km buffer from around shoals within this area in order to avoid impacts to these features from potential future tie-backs. The preferred Crux platform location shown in **Figure 5-3** will be located within an approximate 1 km radius of this location.

The in-field development area also encompasses the marine environment that may be affected by planned discharges, as identified from modelling which is presented in **Section 7.**

The export pipeline route connecting the Crux platform to the Prelude FLNG facility includes a 1 km buffer either side of the proposed route where minor deviations in the final pipeline route may occur, as shown in **Figure 5-4**. A slightly larger buffer (approximately 2 km) has been allowed at the Prelude end of the pipeline to allow for tie-in to the most appropriate quadrant of the FLNG turret.

The OPP is only required to assess petroleum activities, as defined in Regulation 5A(5) of the OPGGS (E) Regulations. The project area also covers the area that project vessels, carrying out petroleum activities, may be moving, such as installation vessels and pipelay vessels when they are installing subsea facilities. This OPP does not include the general transit of vessels to or from the project area. These activities will be undertaken in accordance with relevant maritime legislation, such as the Commonwealth *Navigation Act 2012*, and are within the jurisdiction of AMSA. In addition, helicopter activities outside of a petroleum safety zone are not defined as petroleum activities. Further, the fibre optic cable installation and operation is not considered a petroleum activity. Therefore, activities undertaken by the vessels and helicopters which are not carrying out petroleum activities are not considered in this OPP. Therefore, any assessment outside of these activities are provided for Shell internal Environmental, Social and Health Impacts (ESHIA) purposes, outside of the formal OPP process, to support the transparent, whole-of-project impact assessment process.

Onshore support facilities required during construction, commissioning and operation will be located in existing ports and associated industrial areas. It is expected that the Crux project will utilise the onshore supply base facilities (Kimberley and NT) that are used to service the Prelude FLNG facility. In general, the Crux project will seek to utilise existing support facilities and services used for the Prelude FLNG project. Given the nature of the Crux project, is not expected to significantly increase the demand on these facilities/services. Where required, the operation of these onshore support facilities is subject to relevant State and Territory Government approvals processes and is therefore outside the scope of this OPP.

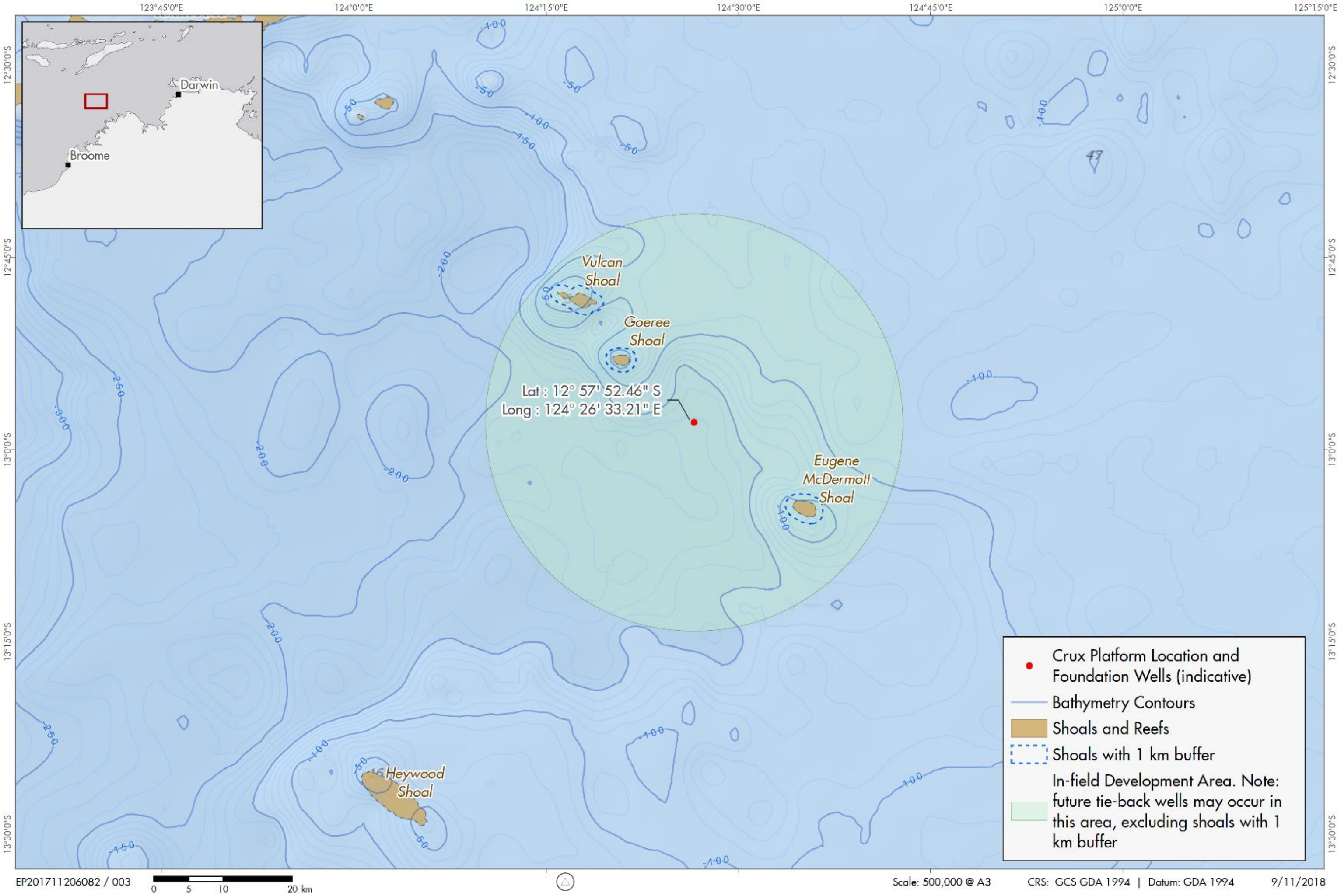



Figure 5-3: In-field Development Area

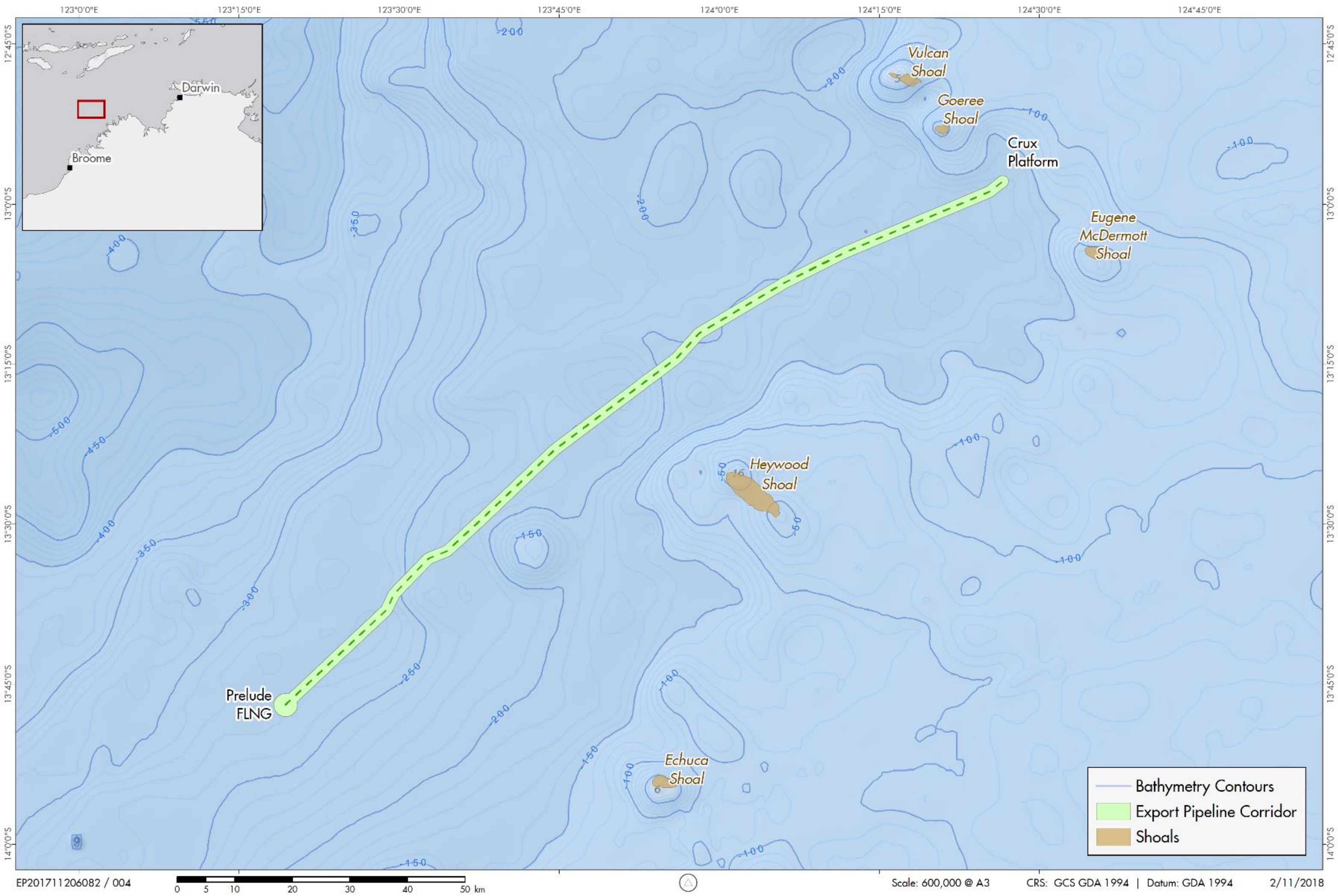



Figure 5-4: Export Pipeline Corridor

## 5.4 Project Schedule

As outlined in **Section 1.1**, FEED engineering for the project commenced in 2019 with the FID currently anticipated to occur in 2020. From FID it will take approximately 4 to 5 years for the platform to be fully designed, constructed off-site and towed to location. Whilst the platform is being built, the subsea production wells would be drilled and suspended until installation of the platform facilities, after which the wells would be completed, hooked-up to the platform and brought online.

The indicative timeframes and development schedule of key project activities are presented in **Table 5-1**.

Table 5-1: Indicative Project Timeline

| Project Stage | Target Date/Timeframe |
|---|---|
| Foundation development drilling – including well tie-back to the platform and well completion | Between approximately 2–4 years post-FID |
| Subsea installation and hook-up – platform, export pipeline and subsea integration system | |
| Commissioning | Approximately 4–5 years post-FID. However, timing will be influenced by completion of the foundation development drilling and subsea installation and hook-up activities. |
| Operations – including potential future subsea tie-backs to the platform | The Crux platform and pipeline will have a design life of 20 years. However, subject to future investment decisions, operations may extend platform and pipeline life.<br>The installation of any subsea infrastructure required to support future subsea developments (i.e. flowlines, risers and manifolds) within the in-field development area may be undertaken during operations. |
| Decommissioning | Decommissioning activities will be undertaken at the end of the operational life of the Crux project. |

## 5.5 Crux Project Description

The Crux project, inclusive of any potential future subsea tie-backs, will comprise:

- platform (fixed jacket) and topsides processing facilities
- production wells with dry tree completion
- export pipeline and associated subsea integration system, and
- subsea facilities (e.g. flowlines, risers and manifolds) associated with any future subsea tie-backs.

### 5.5.1 Crux NNM Platform

#### 5.5.1.1 Platform Sub-structure

The fixed jacket platform will be held in position by piled foundations, based on current sub-structure engineering definition. To support the weight of the platform topsides, each of the four peripheral jacket legs will be secured to the seabed via piles installed through a skirt pile. The foundations are required to be piled to ensure a rigid connection is maintained between the jacket and the seabed during all weather and sea conditions.

#### 5.5.1.2 Platform Topsides

**Production Facilities**

The topside facilities for each foundation well will comprise a wellhead system, accommodating the production tubing, tie-back strings and dry trees. The individual wellhead systems will be connected into a common production manifold. Space and tie-in points will be installed to accommodate future tie-back tubulars/risers.

**Process Facilities**

The platform topside facilities consist of a single processing train with approximately 2.9 million tonnes per annum (tpa) capacity, which dehydrates the gas and condensate streams for export to the Prelude FLNG facility as a co-mingled stream in the export pipeline.

The facilities comprise air cooling, separation, gas dehydration, condensate coalescer/filter, produced formation water (PFW) treatment and disposal overboard, chemical storage and injection facilities, plus the required power and utility systems. A process flow diagram for the platform is shown in **Figure 5-5**. There is a potential that a compression module could be installed in the future if required to support the development of future fields within the in-field development area.

The air cooler will cool the raw gas arriving at the platform before it passes into an inlet separator that separates gas from the hydrocarbon/PFW fluids. Gas exiting the inlet separator will be dehydrated via a triethylene glycol (TEG) system. The hydrocarbon/PFW fluids from the inlet separator will be cooled and passed to a liquid separator where the PFW will be separated from the condensate. The PFW stream will then be routed to the PFW treatment system while the condensate stream will be routed to the condensate filter/coalescer to remove any residual free water before it is recombined with the dehydrated gas for transfer through the export pipeline to the Prelude FLNG facility.

The PFW will be treated in a system comprising a liquid separator, low shear control valve and degasser vessel. Additional space will also be provided to allow further treatment options, such as hydrocyclones, if issues with the PFW treatment occurs. PFW will be disposed of overboard to the marine environment. Further context on the nature and scale of PFW discharge is covered in **Section 5.7.7**, and the evaluation of potential impacts/risks is covered in **Section 8**.

The platform design has allowed for future field development tie-ins through inclusion of future provisions for subsea tie-backs with flowline approach, riser and connection to the existing topsides manifold.

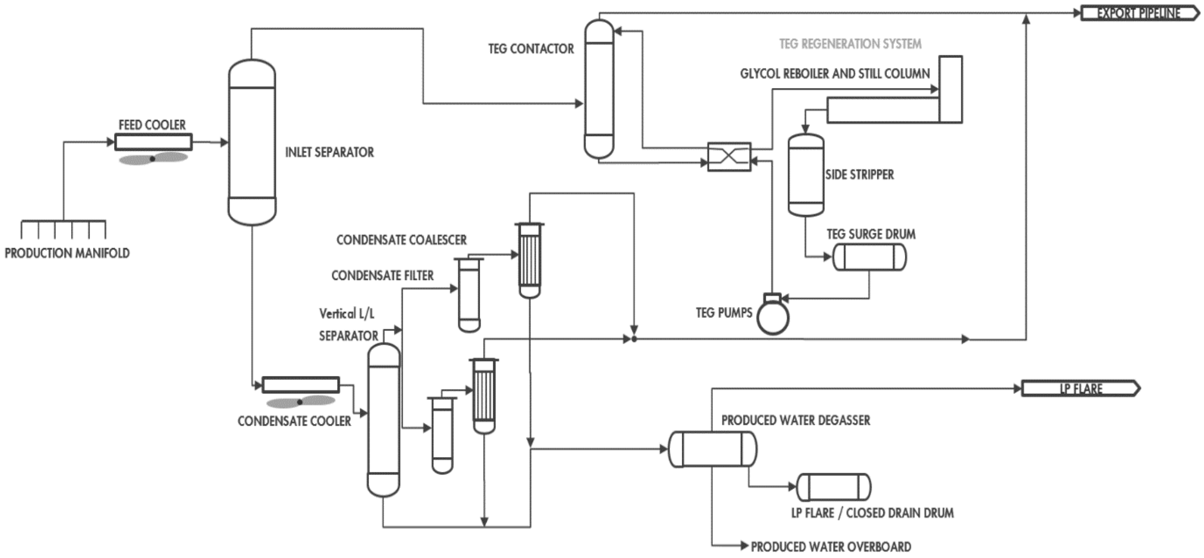



Figure 5-5: Process Flow Diagram for the Crux Platform

**Utilities**

To provide a reliable power supply for the platform process facilities, power will be generated from gas turbine generators installed on the platform topsides.

The platform will include a flare system. The purpose of the flare system is to collect and safely dispose of hydrocarbon-containing vapour that are released during start-up, operations, shutdown and maintenance. During start-up and shutdown, controlled flaring will be necessary.

Potable water will be provided by a lift-on tank for maintenance visits and is proposed to be used for ablutions and maintenance activities, as required. A sewage treatment system may also be installed should accommodation be provided on the platform.

Chemical storage and injection facilities will also be provided on the platform to maintain optimum production. Typical chemicals that may be stored in relatively small volumes (5 $m^3$–100 $m^3$) include corrosion and wax inhibitors, and TEG.

**Operations and Accommodation**

As a NNM platform, the intent is that the Crux platform will be operated remotely from the Prelude FLNG facility. The operations team will utilise existing procedures, method statements and proactive condition monitoring techniques, to monitor and analyse instrumentation and equipment health.

Upon achieving steady state operations, the workforce for campaign and turnaround maintenance will be accommodated on a ‘Walk to Work Vessel’ and access to the Crux platform via a gangway.

The Crux platform design will be such that a future accommodation module can be installed without the need to extend the current platform deck footprint (by installing it above the temporary refuge location). This future accommodation is for the potential future tie-backs should they trigger the requirement for a manned platform.

Temporary accommodation will be provided on vessels, for periods of peak workforce support, such as that expected during installation, commissioning and campaign maintenance/planned shutdowns.

**Maintenance and Sparing**

Maintenance of the platform will consist of campaign maintenance and planned shutdowns for major scheduled maintenance. Planned maintenance will be executed campaign-style for both normal operations and during maintenance shutdowns, with teams attending the platform or onshore workshops where equipment has been transported for overhaul.

### 5.5.2 Production Wells

The current design is for a total of five production dry tree wells. The wells will be drilled and suspended with a semi-submersible rig. Following installation of the Crux platform, the wells will be tied back with rigid concentric tubulars and completed with dry trees using a MPR (or similar completions unit) temporarily installed on the Crux platform.

The deviated wells will be drilled from a single drill centre, which lies within the platform footprint. The location of the drill centre has been selected to optimise for well length and reservoir penetration, and avoidance of any potential subsurface hazards.

The wells for the foundation development are proposed to be drilled in a single campaign. Any future wells will be contained within the in-field development area shown in **Figure 5-3**, and will be conventional subsea wells with subsea trees, tied-back to the platform through subsea infrastructure. This is described further in **Section 0**.

### 5.5.3 Export Pipeline and Subsea Integration System

The export pipeline system is designed to carry gas and condensate from the Crux platform to the Prelude FLNG facility, through an approximately 165 km long 26-inch export pipeline.

The export pipeline route is relatively straight, as shown in **Figure 5-4**, and there are no seabed obstructions. The route slopes downwards towards the Prelude FLNG facility, going from a water depth of approximately 170 m at the Crux platform end to approximately 250 m at the Prelude FLNG facility location.

At the Crux end, a rigid tie-in spool connects the rigid riser on the Crux platform to the export pipeline end termination (Crux PLET). At the Prelude end, the export pipeline will terminate into a Crux dedicated PLET (Prelude PLET), which is proposed to be located approximately 550 m from the FLNG turret centre. A single large bore dynamic, flexible riser will connect the FLNG topsides facilities to the Prelude PLET. Electrohydraulic control to the isolation valves will be provided via the existing Prelude control system or from a dedicated umbilical from the FLNG turret to the Prelude PLET.

A schematic of the export pipeline and subsea integration system in shown in **Figure 5-6.**

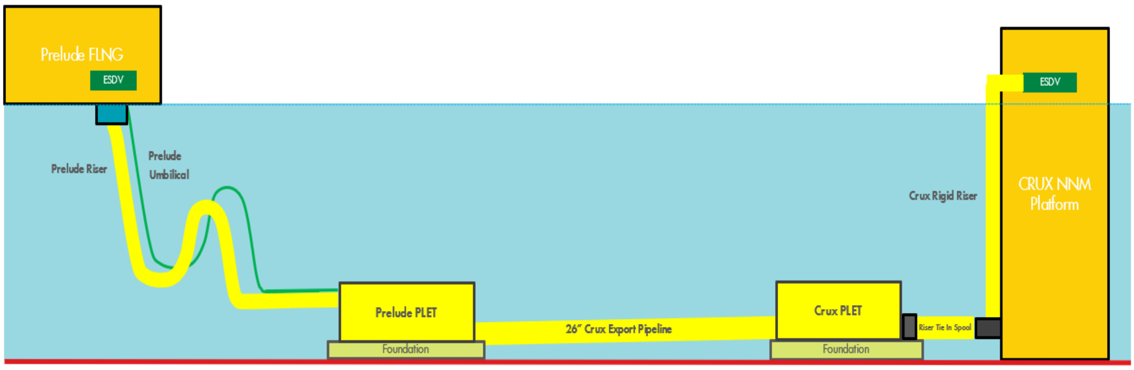



Figure 5-6: Export Pipeline and Subsea Integration System

### 5.5.4 Future Subsea Tie-Backs

As outlined in **Section 5.2**, the project incorporates provisions for future tie-back of subsea developments within the in-field development area to supplement production from the Crux field. The additional gas fields that may be tied-back to the Crux platform within the Crux in field development area are shown in **Figure 5-7** (note, confidential information on exploration prospects is not shown). The locations and extents of the fields are based on current sub-surface information and may be subject to refinement as an outcome of future exploration activities to further characterise the fields. While the exact number of wells to be drilled to support any future subsea tie-backs is to be determined, the total number is anticipated to be up to 10 subsea wells. These wells will be drilled within the boundaries of the additional fields, as shown in **Figure 5.7**.

Space allowances will be included in the Crux platform to enable subsea control systems and risers to be retrofitted if required. In addition to space allowances, the platform structure will be designed to enable a future cantilevered module. This module will be used for hydrocarbon processing, including potentially compression. Additional facilities and infrastructure associated with subsea tie-backs would also need to be installed for up to three separate subsea manifolds, subsea tree systems, flowlines and risers. The manifolds would collect and transfer fluids from the fields from the subsea wellheads into the platform. While details will be further considered as staged development progresses, it is possible that subsea compression may be utilised to minimise the size of a future module that may need to be added to the platform.

The reservoir properties, geochemistry and pressures of the surrounding fields that may be tied-back in future are comparable to the Crux field. This includes properties directly related to PFW and hydrocarbon characteristics (refer to **Section 8.4.8.2** and **Section 8.4.9.2** for further detail). The operating range of the Crux platform is therefore considered wide enough to safely produce the hydrocarbons and water expected from these surrounding potential fields. This operating range incorporates such considerations as operating pressures, compatible metallurgy and resulting produced formation water composition. The information used to design this envelope is based on a number of regional studies to establish expected producing pressures, gas and condensate flow rates, and flow stream contaminates such as $CO_2$, mercury and hydrogen sulphide ($H_2S$). The types of reports used to gather this information and establish regional understanding comes from reliable sources, including publicly available well completion reports (drilling data), seismic surveys available from Geoscience Australia, as well as other regional studies conducted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The synthesis of this regional open-file data shows the potential surrounding fields to contain gas-condensate, with similar flow capacity, reservoir pressure and water chemistry to that at Crux.

Shell requires high confidence that the hydrocarbons received by the Prelude FLNG facility must meet a number of specifications to allow them to be processed on the FLNG facility. As part of Shell's stage gate process, a number of assurance studies were completed to assess whether the Crux field hydrocarbons were able to be received and processed by the Prelude FLNG facility. The Prelude project required that the specifications for the Crux field hydrocarbons delivered for Prelude ensured the Prelude FLNG facility continued to operate within operational, design and integrity limits, whilst also providing some margin to operating conditions (to avoid off-specification events).

Given the above, Shell provides high certainly that the properties for the additional fields within the in-field development area are comparable with the Crux field parameters.

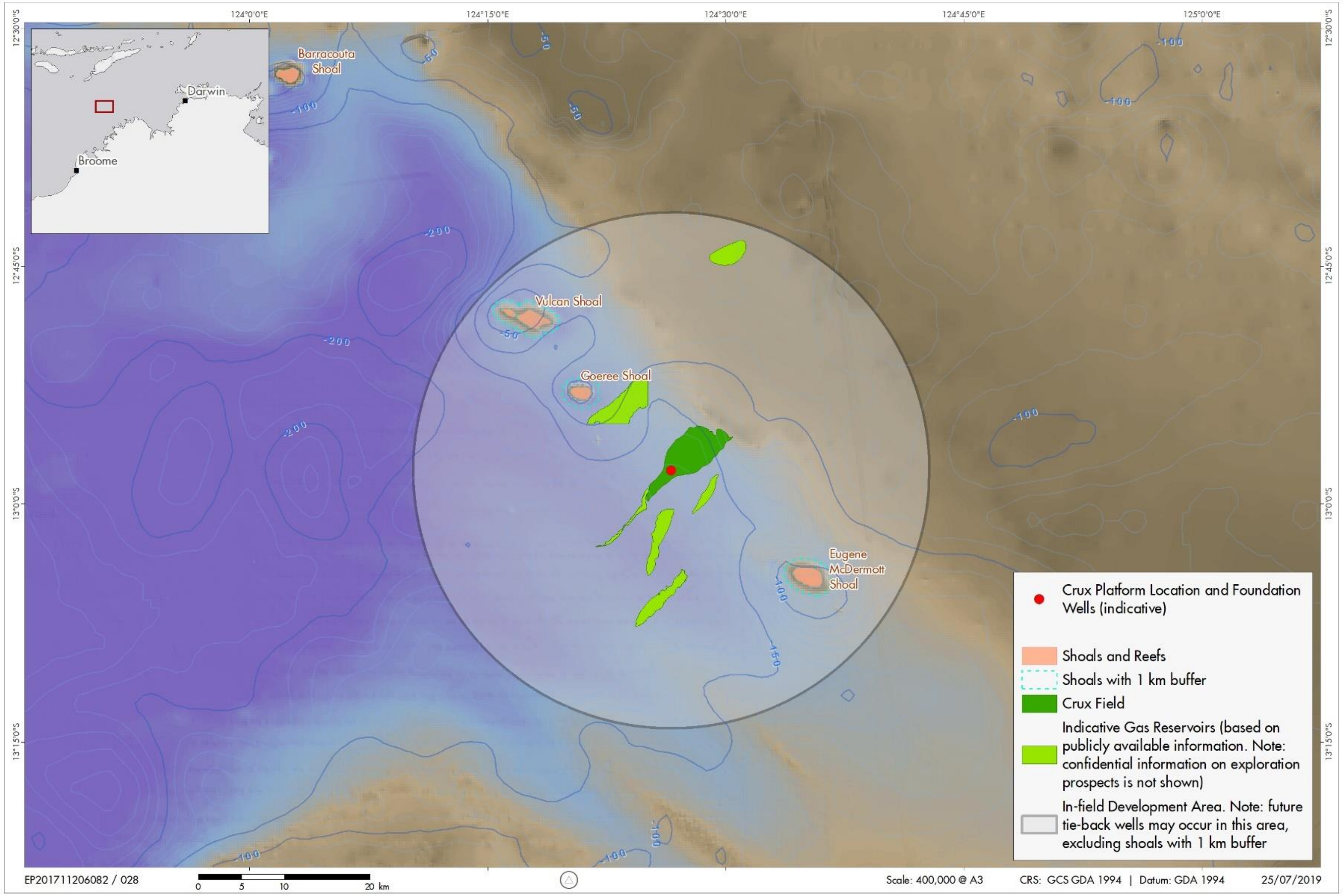



Figure 5-7: Locations of Additional Fields within the Crux In-field Development Area

## 5.6 Project Stages

### 5.6.1 Overview

The key execution stages of the project are:

- development drilling, including tie-back and dry tree completion
- installation of the platform jacket and topsides
- installation and hook up of export pipeline and subsea integration system to the platform facilities
- commissioning
- operations and maintenance (note, this includes any future subsea tie-back developments within the in-field development area), and
- decommissioning.

The key activities within these project stages are summarised in **Table 5-2**.

As outlined in **Section 5.3.1**, additional gas fields within the in-field development area may be tied back to the Crux platform. The development of these fields will broadly involve the same key stages and activities as those used in the development of the Crux field, with the exception of completion with subsea trees.

Table 5-2: Crux Project Stages and Key Activities

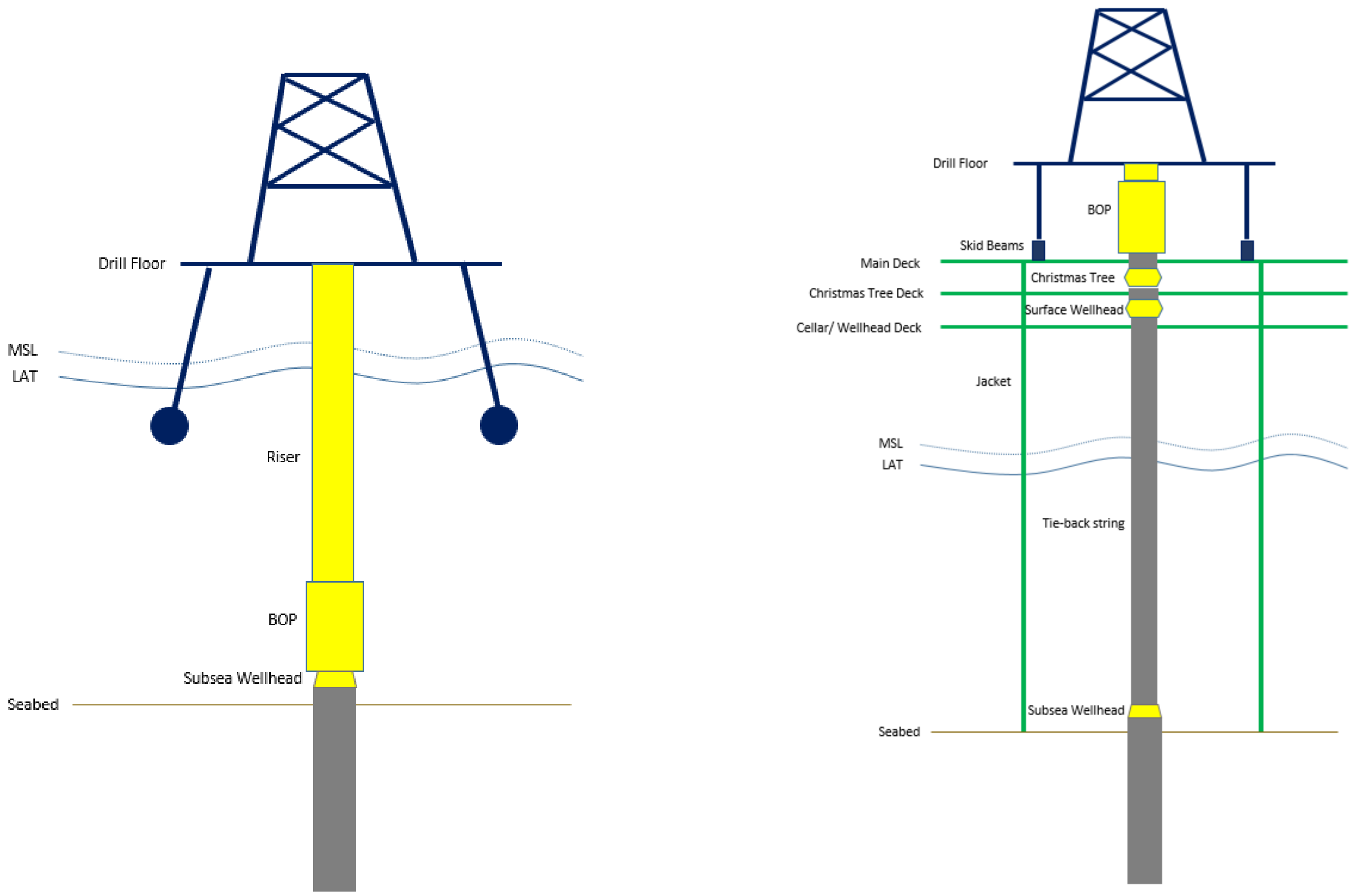
| Project Stage | Key Activities |
|---|---|
| Development drilling – including well tie-back to the platform and well completion | • Drilling and temporary suspension of production wells<br>• Foundation wells tied-back and completed with dry tree using a MPR (or similar completions unit) temporarily installed on the Crux platform<br>• Wells perforated and unloaded with a coiled tubing unit and a temporary test package |
| Installation and hook-up of platform, export pipeline and subsea integration system | • Transport, installation and piling of jacket<br>• Transport and installation of platform topsides<br>• Installation and pre-commissioning (e.g. hydrotesting and dewatering) of export pipeline<br>• Installation of subsea integration system, including Crux PLET, Prelude PLET and risers |
| Commissioning | • Commissioning testing and monitoring topside equipment on the platform and the export pipeline |
| Operations and maintenance | • Well, flowline and riser operations<br>• Remote production and processing operations<br>• Planned maintenance and shutdown campaigns<br>• During operations, additional fields within the in-field development area may be developed. Key activities associated with the development of these fields may include:<br>  o installation and commissioning of subsea facilities to support future subsea tie-backs<br>  o installation and commissioning of future compression module |
| Decommissioning | • Well abandonment<br>• Decommissioning of the platform<br>• Decommissioning of subsea facilities and export pipeline |

### 5.6.2 Development Drilling

The initial Crux production wells are proposed to be drilled with a semi-submersible drilling rig and later completed from the Crux platform using a temporary MPR (or similar completions unit). As the semi-submersible rig will drill (but not complete) the wells prior to the installation of the platform, the wells will be temporarily suspended until the Crux platform installation. Following the platform installation, a MPR/completions unit will tie-back the wells to the platform through rigid concentric tubulars, production tubing run and wells completed with dry trees. The MPR/completions unit will then be removed from the Crux platform. Subsequently, it is anticipated that the wells will be perforated with a coiled tubing unit and unloaded to a temporary test package. The drilling strategy is conceptualised in **Figure 5-8**. Any future wells will be subsea wells, drilled and completed with subsea trees using a semi-submersible drilling rig, and tied back to the platform through subsea infrastructure.

Drilling conducted from a semi-submersible drilling rig will use standard offshore drilling methods. Five production wells are proposed and are anticipated to be drilled within an approximate two-year period. Three additional spaces will be provided on the platform as contingency slots for the five foundation wells.

During drilling the rig will require supply vessels to visit every two or three days to replenish materials and equipment, and refuelling (diesel) once every 2–3 weeks.




a) Semi-submersible Drilling Rig

b) Tie-back and Completion using an MPR/completions unit

Figure 5-8: Conceptual Development Drilling Strategy

#### 5.6.2.1 Drilling Method

The wells will be drilled through a subsea drilling template, which may be installed with the semi-submersible drilling rig or as part of a dedicated campaign. The drilling template ensures correct positioning of the wells and alignment with future platform facilities. It is anticipated that dedicated docking piles will be installed, to facilitate installation of the platform substructure over the drilling template. Docking piles and the subsea template will remain in place for the producing life of the NNM platform.

The wells will be drilled in sections which decrease in diameter at increasing depths until the target reservoir is reached. Protective steel casing is inserted into the wells and cemented in place to isolate each section from the subsequent sections and provide structural support and stability to the well.

In the process of drilling, drilling muds (also known as drilling fluids) will be used to lubricate and cool the drill bit, maintain well bore stability, and remove drill cuttings (i.e. rock fragments) from the well sections as they are drilled. Two types of drilling muds will be used to drill the wells; water-based mud (WBM) and synthetic based mud (SBM). SBM will be used on the deeper and more challenging well sections where improved wellbore stability and suitability of the mud system for higher temperatures is required. WBM will be discharged to sea at the end of their useful life or at the end of the drilling program, whereas SBM is recovered and returned onshore for recycling or disposal.

**Table 5-3** presents the types of drilling fluids, and their typical components, proposed to be used for the different well sections. The final selection of drilling fluids will be undertaken once detailed well design information is available to ensure that drilling fluids are appropriate for the drilling conditions. Based on the current well design and information from previous drilling campaigns undertaken by Shell for Prelude and the Auriga West-1 well, it is expected that the volume of drilling fluid discharged will be < 5,000 $m^3$ per well.

Drilling fluids and cuttings will be discharged at the seabed during drilling of the upper well sections as a riser connecting the drilling rig to the wellhead will not yet be installed. An alternate option of a riserless mud recovery system is being considered and may be used for the riserless well sections. This system allows cuttings to be recovered at the surface (i.e. drilling rig); however, the cuttings would still be discharged to seabed (if drilled with WBM), but not immediately above the well location.

On installing the riser system, the drilling fluids and cuttings will be circulated to the drilling rig prior to discharge overboard. Based on available information, it is estimated that the volume of drill cuttings discharged during conventional operations is not anticipated to exceed 1,000 $m^3$ per well. Cuttings from sections drilled with SBM are passed through a treatment system onboard the drilling rig prior to discharge overboard to reduce the volume of synthetic mud coating the rock. Previous experience from Prelude suggests that the residual SBM base fluid on cuttings content will be less than 10% weight per weight (w/w), averaged over all sections using SBM, prior to discharge overboard.

A subsea blowout preventer (BOP) will be installed prior to drilling the lower well sections for well control purposes during drilling. The BOP is removed once drilling is complete. Function and pressure tests of the BOP will be conducted regularly throughout drilling to ensure the system reliability is maintained. Each function or pressure test of the BOP will result in approximately 300 L of BOP hydraulic fluid (i.e. hydraulic fluid chemical diluted in water), depending on the BOP specifications, being discharged to the marine environment.

Once all sections of the well have been drilled, cased and cemented, the well will be temporarily suspended with suspension plugs, inflow tested and monitored until the Crux platform is installed.

Following installation of the platform, a MPR/completions unit will be used to tie the initial production wells back to the platform via one or more tubulars. This requires the use of a surface wellhead system. Subsequently, a BOP will be installed, well suspension plugs recovered, and the production tubing will be run. Following well completion, the BOP will be removed, and the dry trees installed. The dry trees control the flow of the well, allow for pressure and temperature monitoring, and also provide a means of access for well intervention in the event down hole (well) checks or modifications are required.

The section of the well within the target reservoir (i.e. the production liner) will be perforated to allow the reservoir fluids to flow into the well. Prior to production, the wells will be cleaned up to remove any remaining drilling fluids, solids and debris. During clean-up, gas and condensate will be flared using temporary burner booms. Any water from the clean-up operations will be discharged overboard, provided it meets oil-in-water specifications, or shipped and treated onshore. It is anticipated that this will be part of a rigless campaign. The wells are then ready for production.

The persons on board (POB) required for well completion, perforating and unloading operations on the NNM platform will be accommodated on a floating accommodation support vessel.

Table 5-3: Drilling Fluid Types and Typical Components

| Well Section Diameter (inches) | Drilling Fluid Type and Typical Main Components |
|---|---|
| Tophole (size yet to be confirmed – notionally 42” and 32”) | WBM – seawater and high-viscosity gel sweeps |
| 17.5 | WBM – generally consists of seawater base fluid with bentonite clay, barite, brine and gellents (e.g. guar gum or xanthum gum) |
| 12.25 | Detailed SBM formulation is still to be determined but the drilling fluid may include synthetic base fluid with bentonite clay, barite, fluid loss control agents, lime, aqueous chloride, bridging agents and emulsifiers |
| 8.5 | |

### 5.6.2.2 Vertical Seismic Profiling

While vertical seismic profiling (VSP) is not expected to be required for the development drilling of the initial Crux production wells, VSP may be performed at some stage in the Crux project, such as during future drilling campaigns within the in-field development area for backfills to the Crux platform. VSP may also be performed on a targeted basis during operations as part of well flow management. The use of VSP in these instances will be through deployment of a single small sound source from the drilling rig or Crux platform in the water column while receivers are positioned at specific depths downhole within the well. VSP provides a seismic image of the geology in the immediate vicinity of the well, with the survey taking approximately eight to 24 hours per well.

### 5.6.3 Installation and Hook-up of Facilities

#### 5.6.3.1 Crux NNM Platform

The platform jacket and Crux rigid riser will be constructed off-site and transported to the Crux location by an offshore installation vessel(s). On arrival, the platform jacket will then be installed at location and fixed to the seabed by piled foundations using a construction vessel. Drilling is likely to be undertaken to assist in the installation of the piled foundations. The platform topsides will be installed via a floatover.

#### 5.6.3.2 Export Pipeline and Subsea Integration System

The export pipeline system will be installed in several phased campaigns, these being:

- Prelude FLNG facility integration
- export pipeline installation, and
- Crux platform integration.

The Prelude FLNG facility integration scope, consisting of the large bore flexible riser and associated dynamic umbilical, will be installed using a specialised flexlay vessel. The flexible riser and dynamic umbilical will be designed to allow for extended wetparking while the rest of the export system is installed.

The rigid export pipeline and associated Crux PLET and Prelude PLET will be installed in a separate campaign, utilising specialised large bore rigid pipeline vessels with heavy lift capability. Prior to laying of the export pipeline, the Crux PLET and Prelude PLET will be installed on the seabed using installation vessels with heavy lift capability.

The export pipeline will be installed by a pipelay vessel. An S-lay method of installation will be used and involves lengths of steel pipe (joints) being continuously welded, inspected and coated with (anti-corrosion and concrete coating) in a horizontal working plane (firing line) on board the pipelay vessel. As the pipelay vessel moves forward along the pipeline route, the pipe gradually exits the firing line, curving downward through the water until it reaches the seabed. The stability of the pipeline on the seabed is achieved through the addition of concrete weight-coating. No trenching or rock stabilisation of the export pipeline is envisaged. Some rectification or stabilisation of the pipeline (e.g. installation of grout bags, concrete mattresses etc.) may be required in localised sections where there are large free spans, to ensure the stability and integrity of the pipeline is maintained. Additionally, jetting techniques using a remotely operated vehicle may be used in these localised sections to improve pipeline stability.

Crux integration will be achieved by the installation of the rigid tie-in, connecting the Crux PLET to the Crux rigid riser. Integration at the Prelude FLNG facility is completed by connecting the large bore flexible riser and dynamic umbilical to the Prelude PLET. It is expected that an installation vessel/multi-purpose support vessel will be used to install the Crux PLET and Prelude PLET.

Pre-commissioning of the export pipeline will likely include the following activities:

- flooding, cleaning and gauging
- process/pressure testing using treated seawater to confirm structural integrity
- dewatering and drying, and
- pipeline inerting using nitrogen purge.

The pre-commissioning activities will require the use of PIGs. The pressure test fluid will be discharged to the marine environment from the Crux platform or Prelude FLNG facility end of the pipeline. Further context on the nature and scale of hydrotest discharge is covered in **Section 5.7.7**, and potential impacts/risks covered in **Section 8**.

#### 5.6.3.3 Future Subsea Facilities

Subsea facilities required for any future developments will be installed and connected to the platform using a combination of specialised offshore installation vessels, such as crane vessels and subsea construction vessels.

While trenching of the flowlines/risers will not be required, some secondary stabilisation may be needed in some areas to ensure the stability and long-term integrity of the subsea facilities.

#### 5.6.3.4 Supporting Infrastructure - Fibre Optic Cable

A fibre optic cable will be installed to connect the Crux platform to the existing North-West Cable System, which connects both the Prelude and Ichthys projects to Port Hedland and Darwin. The cable will provide the project with reliable and high-speed data communications that allows efficient and responsive operation of the Crux platform topside facilities remotely. The fibre optic cable will branch off the existing North-West Cable System (operated by NEXTGEN) and is anticipated to be approximately 50 km in length. There is also another option that the cable may be laid along the export pipeline route from Prelude to the Crux platform. The cable route has not been determined given the early stage of the project.

The cable is anticipated to be around 10 mm–40 mm in diameter and will be installed using a specialised vessel. The cable is expected to the buried along the majority of the route to provide extra protection and stabilisation. A combination of standard techniques may be used to bury the cable, including ploughing/trenching concurrently with the laying of the cable and post lay burial via jetting techniques through use of a remotely operated vehicle.

The forward approvals process for the installation and connection of the cable is subject to financial and commercial arrangements, and the timing of other customer negotiations and connections.

### 5.6.4 Commissioning

It is anticipated that the majority of the commissioning activities of the Crux platform will take place at the construction yard, with only limited commissioning activities of the platform occurring within the in-field development area. Key steps in the offshore commissioning process of the platform are expected include:

- cold venting to clear nitrogen from the equipment and piping systems
- lighting the pilots for the flare system
- sequential pressurisation of topsides systems and final leak checks
- fuel gas system commissioning to start main power generation
- commissioning of condensate and gas dehydration systems, and
- when export specifications have been met, the gas production rates will be slowly increased to system capacity.

Supply vessels will ship materials, equipment and other supplies, such as food, in support of commissioning and start-up activities. During commissioning, there will be temporary support requirements, including temporary power generation (diesel), temporary offices and services (for water, nitrogen etc).

### 5.6.5 Operations and Maintenance

The platform will require a medium sized operational team in early production life, following commissioning and start-up activities. It is likely this will be provided via floating accommodation such as vessels to accommodate personnel. The facility will be designed such that it can employ a Walk To Work vessel as means of accommodation. The Walk to Work vessel will be equipped with heave compensated gangway allowing transfer of personnel on and off the facility. Remote, NNM operations, are expected to be in place after approximately 12 months from the wells commencing production.

The following operational activities are anticipated to occur throughout the life of the facility:

- start-up, ramp-up and shut-in of individual wells
- remote chemical injection into the well-streams
- remotely monitoring and control of the platform
- well-testing
- well, flowline and export pipeline integrity management
- well intervention works, including water shut-off, valve installation, suspension plug installation for tree replacement, re-perforation or upper completion (e.g. tubing, subsea isolation valves) replacements
- campaign and shutdown maintenance execution along with unplanned interventions, and
- intelligent pigging of export pipeline.

Inspection and intervention on the subsea facilities will be undertaken when required using specialised intervention vessels.

Integrity and inspection through pigging of the export pipeline may be undertaken throughout operations to ensure structural integrity of the pipeline is maintained and remove any residual materials, such as deposited wax, that may have accumulated in the pipeline. Pigging refers to the practice of using PIGs to inspect or clean the pipeline without stopping the flow of the product in the pipeline. Pigging will be performed from the PIG launcher/receiver located on the Crux platform to the Prelude facilities. Pigging frequency will be determined based on a risk-based inspection process and ongoing monitoring of corrosion controls. Small volumes of liquids or solids may be released to the marine environment during operational pigging activities.

A flow assurance management strategy has been defined for the project to ensure efficient and sustained operability of the production facilities. While the risk of hydrate formation and plugs building up in the export pipeline is low, a hydrate surveillance and remediation strategy will be implemented throughout operations to monitor for the formation of hydrate plugs.

There is a low likelihood of wax deposition occurring in the export pipeline and provision for continuous paraffin inhibitor injection has been assumed throughout the field life in case this occurs. A fluid sample surveillance program will also be in place for wax deposition analysis during initial production and new wells coming online. If required, pigging of the export pipeline will be undertaken.

Transition to a NNM platform personnel manning philosophy is expected to take approximately one year from start-up. The manning philosophy during this period comprises several phases:

- early operations phase (manned) – following commissioning and start-up activities, personnel will be maintained to provide operational and maintenance support until the platform facilities are operating satisfactorily. During this phase the operations model will be a typical offshore rotational model. This team will operate and maintain the platform until reliability is such that operations numbers onboard can be reduced. The early operations phase is anticipated to be approximately 3 months.
- interim operations model – following early operations and once steady state operations are achieved, the number of personnel will be reduced to a sufficient number to undertake field operations and maintenance. A minimum operations crew is retained until reliable remote operation has been demonstrated. This phase is anticipated to be approximately 6 to 9 months.
- NNM phase – it is anticipated that the facility will move to a NNM operating model within the first year of operation. At this time the facility will be periodically visited during planned campaign and other maintenance activities.

### 5.6.6 Decommissioning

The project will be decommissioned at the end of its operating life when production from the reservoirs ceases to be economically viable. The project will be decommissioned in accordance with the prevailing legislation at that time. Decommissioning is a petroleum activity and requires approval under the OPGGS Act, including acceptance of the Decommissioning EP and Safety Case prior to decommissioning activities commencing.

The overarching objective of decommissioning will be to ensure that activities do not cause unacceptable environmental impacts and are the most appropriate for the circumstances at the time in which decommissioning option is undertaken.

The complete removal of infrastructure and the plugging and abandonment of wells is the default decommissioning requirement under the OPGGS Act and is consistent with Australia's international obligations to remove disused installations and structures. However, this requirement is subject to other provisions of the OPGGS Act and regulations, directions given by NOPSEMA or the responsible Commonwealth Minister, and other applicable laws such as the *Environmental Protection (Sea Dumping) Act 1981*. Therefore, alternative options other than complete removal can be undertaken if the titleholder can demonstrate that the alternative approach delivers equal or better environmental, safety and well integrity outcomes (DIIS 2018). The OPGGS Act allows titleholders to make alternative arrangements for the treatment of equipment (e.g. partial removal or abandonment in situ) through the submission of an EP that includes decommissioning activities, provided that these arrangements and that impacts and risks are acceptable and ALARP (NOPSEMA 2017).

Infield decommissioning activities are expected to take several years to complete. Prior to decommissioning, an EP will be submitted to NOPSEMA for acceptance after considering a range of decommissioning options, including but not limited to those outlined below for project infrastructure, and will present an ALARP assessment of the appropriate strategy at that time:

- plugging and abandonment of production wells
- NNM platform – options may include cutting off at the base and total removal of topsides for onshore disposal, leave in situ, jacket toppling or offshore reefing
- subsea infrastructure (e.g. risers, Crux PLET, Prelude PLET, manifold, jacket/foundation) – options may include removal and onshore disposal, leave in situ, jacket toppling, or offshore reefing, and
- export pipeline, flowlines and fibre optic cable – options may include total removal, leave in situ after flushing to remove hydrocarbons, or partial removal.

After the successful completion of decommissioning activities, Shell will apply to surrender the Crux production and infrastructure licences. Once satisfied that Shell has complied with all requirements for the surrender of these licences, the Designated Authority can give consent to the surrender of the licences. It is likely that decommissioning and surrender of the licences, from approval of the Decommissioning EP through to the Designated Authority's consent to the surrender of the licences, will take about 12 months.

It is widely acknowledged that there are a variety of factors that may affect titleholders' consideration of the most suitable decommissioning option, including site-specific environmental and safety risks, type of infrastructure, costs and available technology. An ALARP and acceptability assessment of the decommissioning options proposed for the project will provide transparency in decision making where environmental benefits and impacts are clearly presented in the context of a broader framework of decision criteria.

Given the early stage of the project, and the expected operational life of the project, it is premature to define a decommissioning strategy that aims to address environmental impacts in detail in this OPP. Key decommissioning risks have been broadly addressed through the evaluation of project impacts and risks in **Section 8**. Further detailed information of the nature and scale of the activity, potential environmental impacts and risks, and the control measures that will be implemented will be provided in the activity-specific Decommissioning EP. As such, this OPP only outlines broad EPOs relating to decommissioning activities, as aligned with the intent for this to be an 'early stage, whole-of-project' assessment.

While the majority of decommissioning will be undertaken at the end of the project's operating life, Shell will look for opportunities throughout the operations phase to periodically remove any disused infrastructure, where feasible.

## 5.7 Key Project Aspects

Key aspects associated with project activities that can interact with the environment are described in **Section 5.7.1** to **Section 5.7.9**.

### 5.7.1 Physical Presence

The physical presence of the project will arise from the installation of physical features, such as wells, well tie-back infrastructure, subsea facilities and the export pipeline, and from the presence of the Crux platform and project vessels. These offshore facilities/infrastructure and equipment will be present both at the sea surface (e.g. platform and project vessels), within the water column (e.g. platform jacket and risers) and on the seabed (e.g. flowlines, manifold, PLET and the export pipeline). While not a planned activity, the potential for dropped objects exists and may interact with the seabed on a very localised basis. The presence of project vessels is considered in detail within the vessel movements aspect, as discussed in **Section 5.7.2**.

Installation and other works, such as anchoring, associated with the following components of the project will disturb areas of the seabed:

- Crux platform (jacket structure)
- drilling and installation of wells
- export pipeline and subsea integration system (e.g. Crux PLET and Prelude PLET), and
- potential future subsea facilities associated with well and tie-back infrastructure.

During drilling and installation stages of the project, the semi-submersible drilling rig and some installation vessels will be held in place using anchors. The exact anchoring configuration will vary for each installation vessel. Physical disturbance of the seabed will mainly be associated with laying and retrieval of anchors and chains. A mooring may also be installed within the Crux in-field development area for use during the project.

The expected approximate area extent of direct seabed disturbance is provided in **Table 5-4**.

Table 5-4: Proposed Direct Seabed Disturbance

| **Facility** | **Approximate Area of Disturbance ($m^2$)** |
|---|---|
| *Crux Field* | |
| Semi-submersible drilling rig – anchors and mooring lines | 10,000 |
| Wells (5) | 45 |
| Vessel anchoring (including mooring) | 200 |
| Platform jacket | 10,000 |
| Export pipeline (1) | 165,000 |
| Subsea integration system (e.g. Crux PLET, Prelude PLET, isolation facilities) | 9,000 |
| Fibre optic cable | 45 |
| *Additional Future Backfills* | |
| Semi-submersible drilling rig – anchors and mooring lines | 30,000 |
| Wells (10) | 90 |
| Subsea integration system (e.g. flowlines and associated umbilicals, manifolds, isolation facilities, PLET) | 90,600 |
| Flowline stabilisations and supports (e.g. buckling structures, mattresses, rock stabilisation) | 1,000 |
| **Total** | **315,980 (approximately 32 hectares (ha))** |

Indirect seabed disturbance may occur as a result of localised sedimentation and turbidity generated from activities associated with the controlled placement of infrastructure on the seabed, such as the drilling template, docking piles, riser base manifold, Crux PLET, Prelude PLET and export pipeline. In addition, the planned discharge of drilling cuttings and fluids during development drilling will also result in a temporary increase in sedimentation and turbidity levels.

### 5.7.2 Vessel Movements

A number of vessels will be required throughout the project to undertake specific activities, as indicated by the summary of the key vessels provided in **Table 5-5**.

Vessel movements within the project area are expected to be highest during the installation phase of the project. Although a number of different vessel types will be used during installation, they will not all be in the field at the same time.

During steady state operations, it is expected that supply vessels will visit the platform during operational maintenance campaigns or planned shutdown to replenish key consumables (e.g. food, water), chemicals and equipment specifically required for scheduled maintenance.

In-field vessels operating within the project area will typically travel at speeds slower than those operating in offshore waters, and therefore exhibit a lower risk profile in terms of interactions with other marine users and marine fauna.

Table 5-5: Key Project Vessels

| Vessel | Project Stage | | | | |
|---|---|---|---|---|---|
| | Development Drilling | Subsea Installation and Hook-up | Commissioning | Operations and Maintenance | Decommissioning |
| Supply vessel | ✓ | ✓ | ✓ | ✓ | ✓ |
| Walk to Work vessel | ✓ | ✓ | ✓ | ✓ | ✓ |
| Offshore support vessels (e.g. drill rig support vessel, well testing vessel, inspection, monitoring, maintenance and repair vessel, survey vessel, infield support vessel, remotely operated vehicle inspection vessel) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Offshore installation/construction/heavy lift vessel | | ✓ | | | ✓ |
| Pipelay vessel | | ✓ | | | ✓ |
| Pipelay barge | | ✓ | | | ✓ |
| Line pipe supply vessel | | ✓ | | | |
| Cable lay vessel (for fibre optic cable) | | ✓ | | | |

### 5.7.3 Light Emissions

Artificial light from activities associated with the project will result in light spill to the surrounding marine environment. Existing sources of light in the vicinity of the project area are limited to vessel movements and oil and gas development activities, with these resulting in temporary illumination. Therefore, the baseline illumination of the project area is predominantly from starlight and the lunar phase and cycle.

All offshore facilities and vessels must meet maritime and operational safety lighting requirements, as specified by Safety Case assessments under the OPGGS Act and relevant legislation, such as the *Navigation Act 2012*. As project activities are conducted 24 hours a day, lighting is required for safety and navigational purposes. Therefore, the Crux platform and project vessels will be constantly lit. The amount of light spill generated in the project area will be dependent on the number of light sources, the wavelength and intensity of the light sources, the location and/or placement of light fittings and the method of light switching.

Light emissions are anticipated to be highest primarily during commissioning and start-up and upset conditions due to the increased presence of vessels and requirement for flaring during commissioning activities. During operations, light from the platform will be predominantly from the pilot flare, which is for process safety requirements, and navigational beacons. Lighting of the platform will be reduced to a minimum during periods when the facility is not occupied. Light emissions from upset flare events will be intermittent and varied in duration.

There will be no permanent lighting within the export pipeline corridor. Project vessels involved in the installation and operational maintenance campaigns will be the only light sources within this area.

### 5.7.4 Underwater Noise

Underwater noise will be produced during all stages of the project from development drilling, installation activities, vessel and helicopter movements, and decommissioning activities. The main sources of noise will be from pile driving activities for the installation of the platform foundations (approximately four piles for each of the four foundations, therefore total of 16 piles) and from vessel engines and machinery. Vessel movements are expected to be higher during the installation and commissioning stages of the project due to the increased number of vessels required (**Section 5.7.2**).

Underwater noise emissions during operations will be relatively limited with noise generating activities expected to be associated with vessel movements only during scheduled maintenance campaigns at the Crux platform. Therefore, the presence of vessels in the project area will be intermittent during the operational life of the project.

Primary access to the Crux platform during operation is expected to be via vessels from Prelude. Helicopters/vessels will transport personnel to/from the platform during commissioning, operational maintenance campaigns and planned shutdowns. It is anticipated that only a single vessel transfer will be required to/from the platform during these periods.

It is expected that helicopters will be used in support of installation phase activities. During operation, helicopters would only be used in the event of an urgent operational need, medical emergency or evacuation. Helicopters have the potential to result in localised underwater noise emissions when landing on/taking off from the platform.

### 5.7.5 Atmospheric and Greenhouse Gas Emissions

Emissions associated with the project will be generated by a number of sources, with most of these being from the Crux platform:

- combustion emissions from power generation and processing facilities
- periodic flaring of gas during development drilling, commissioning/start-up and shutdown activities. A continuous small pilot flame will be necessary on the flare during operations

for safety reasons. This will comprise a continuous flow of small quantities of purge gas and off gas from gas dehydration.

- disposal of TEG regeneration off gas stream to flare
- transportation, such as vessel and helicopter movements, and
- fugitive emissions.

As the Crux project development concept is premised on providing a supply of back-fill gas for the continued operation of the Prelude FLNG facility, the majority of the emissions are accounted for in the design and operation of the Prelude FLNG facility and have been subject to prior assessment and approval through the Prelude FLNG Environmental Impact Statement (EIS) and subsequent EPs. These emissions include the venting of Crux reservoir $CO_2$ (11.6%vol) at the Prelude FLNG acid gas removal unit (AGRU). Therefore the GHG emissions profile that was presented in the Prelude FLNG EIS, and corresponding Supplement, was inclusive of the reservoir emissions of the Crux field and other fields that were anticipated to feed into Prelude, and therefore are not within the scope of this assessment. Alternative options have been considered through the evaluation of the implementation of carbon capture and storage (CCS) at Crux and/or allowances in the design for future implementation of CCS at Crux. It was deemed not currently viable to implement CCS at Crux (for more detail see **Section 5.8**). The GHG emissions profile presented in this OPP is specific to the Crux facility, as relevant to the scope of this assessment. For completeness, a summary of the relative contribution of GHG emissions split between Crux and Prelude facilities, and associated value chain emissions, is provided in **Section 8.4.5,** recognising that the Crux project will contribute to the total cumulative emissions profile that will be received and processed at the Prelude FLNG facility.

The Crux NNM platform process and utilities design is lean, therefore the emission at the platform will be relatively limited. Primary atmospheric emissions include carbon dioxide ($CO_2$), methane ($CH_4$), oxides of nitrogen ($NO_X$), sulphur and volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene and xylene (BTEX).

There is no planned cold venting of hydrocarbons at the Crux platform during operations. There may be unanticipated release of hydrocarbon emissions by venting in the unplanned scenario that the flare pilot flame is not lit, arising from flare tip failure. This is an unlikely scenario, and venting will be of short duration while the flare tip is not operational. There may also be minor fugitive emissions from vents in the onboard diesel storage tanks, or flanges/valves.

#### 5.7.5.1 Emissions

*$CO_2$ and Total GHG*

The main source of $CO_2$ is that produced from combustion of fuel gas in the platform topsides for preliminary processing of the gas and condensate and power generation. The emissions inventory provided in this section accommodates a potential for future compression emissions on the Crux platform. While this is not within the current foundation development concept, an estimation of emissions is provided for completeness. A summary of GHG emissions is provided in **Section 8.4.5**.

The Crux platform process and utilities design will be optimised through the project to minimise GHG emissions.

*$NO_X$*

$NO_X$ emissions will be produced from combustion and flaring operations on the Crux platform and are expected to be approximately 2.5 tpa for foundation scope, and 9 tpa if future compression is added. Relatively minor emissions are expected to arise from products of combustion during other development phases including development drilling and associated vessel activities

*Sulphur*

The $H_2S$ in the feed gas is almost completely removed in the Prelude FLNG facility acid gas regeneration unit and vented. It is expected that approximately 65 tpa of $H_2S$ will be vented with the Crux reservoir $CO_2$. Minor emissions of $H_2S$ or $SO_X$ will be released from the Crux platform as part of the flare gas stream, which will be intermittent and variable over the life of the project.

*Methane*

Methane emissions from Crux are anticipated from potentially fugitive emissions. The total fugitive emissions expected on the Crux platform are in the order of 7,000 tonnes $CO_2$-e per year.

*VOCs*

An key contributing source of VOCs is fugitive emissions that are defined as releases not confined to a stack, duct or vent. These emissions generally include equipment leaks, emissions from bulk handling of products and a number of other industrial operations. Fugitive emissions sources can include connectors and flanges, valves, seals, pumps and compressors.

*Flaring*

Flaring will be required on the Crux platform for commissioning start-up, shutdown, emergency depressurisation and for the disposal of low volume low pressure off gas streams such as TEG regeneration off gas. Apart from the pilot flare, the following flaring events may occur:

- emergency depressurisation – in certain circumstances, this represents the maximum flaring rate required to ensure the topside facilities of the platform are brought to controlled condition as soon as possible. This case results mainly from an emergency shutdown and depressurisation in the topsides. This involves mainly opening of emergency depressurisation valves and is expected to be infrequent.
- operational flaring – operational flaring results from a controlled operational event such as start-up, normal shutdown, system upset, manual controlled blowdown, purging, and draining of equipment in preparation for maintenance. During start-up, there is periodic flaring until the process reaches steady state and stable operations.
- off gas stream disposal – low pressure off gas streams such as off gas from the TEG regeneration system and flash gas from water treatment system will be routed to flare.

### 5.7.6 Invasive Marine Species

Invasive marine species (IMS) are non-indigenous marine fauna or flora that have been introduced into an area beyond their natural geographical range, and may have the ability to survive, reproduce and establish a population such that they threaten native species through increased competition for resources and/or increased predation.

The drilling rig, vessels and equipment sourced from outside Australian waters have the potential to introduce or transport IMS to the project area, or potentially to other areas through activities such as support vessel interaction with the project area. There are two primary mechanisms which may cause the inadvertent introduction and spread of IMS; hull fouling (biofouling) and ballast water discharges.

The project will be managed in accordance with all relevant Australian and international regulations, requirements and guidelines.

### 5.7.7 Liquid Discharges

Liquid discharges will be released to the marine environment throughout the life of the project. The key discharge streams are discussed in further detail below and are considered to represent the largest planned discharges associated with the project. The full range of potential planned liquid discharge sources that may be released at different stages of the project will be assessed and defined as the engineering design progresses.

**Produced Formation Water**

PFW is water that occurs naturally within the same rock strata as the hydrocarbons and flows to the surface with hydrocarbon from the production wells. It comprises condensed water and saline formation water.

The characteristics of the PFW discharge will transition during the life of the project. The water production profiles for the project during early operations predict condensed water during which there is minimal formation water produced. During later operations, the water produced will transition to a mixture of condensed water and formation water. The amount of formation water is expected to comprise a greater proportion of the discharge as the field nears end of life.

PFWs are saline and contain a mixture of dissolved inorganic salts, dispersed oil, dissolved organic compounds, treatment and workover chemicals, dissolved gases, and dispersed solid particles. The elements of the PFW discharge stream that may represent an environmental risk include:

- BTEX compounds – benzene, toluene, ethylbenzene, xylene
- NPD compounds – naphthalene, phenanthrene, dibenzothiophene
- PAH compounds – polycyclic aromatic hydrocarbon compounds, which include acenaphthylene, fluoranthrene and chrysene
- metals – cadmium, chromium, copper, lead, nickel, zinc, iron, barium, mercury and strontium, and
- production chemicals – such as scale inhibitors, corrosion inhibitors, wax inhibitors, biocides, TEG and monoethylene glycol (MEG).

Data from the investigation of the Crux field formations has shown the volume of PFW produced from the gas reservoir will increase towards the end of field life. A maximum water flow rate of approximately 238 $m^3$/day is expected during early operations.

After this time, there is a potential for wells to start producing formation water. Reservoir modelling shows water breakthrough may result in water flow rate increasing to the maximum water flow rate that can be produced from a well. The produced water system on the Crux facility has been designed to handle one well at peak formation water rate after approximately 8 years of production and two wells towards the end of field life (3,180 $m^3$/day formation water).

The modelling and assessment of the potential environmental impact associated with PFW has taken into consideration early field life maximum and maximum peak PFW flow rates, as described in **Section 8**.

Non-routine events resulting in off-specification oil-in-water discharge of PFW could occur. Such events are expected to be infrequent and will be rectified as soon as is practicable and does not represent a typical discharge concentration during routine operations. During commissioning or process upsets, such events are considered more likely. Shell has taken this into account in the project concept engineering and evaluation of alternatives (refer **Section 5.8**) and the assessment of relevant impacts and risks with this discharge stream (**Section 8**).

**Wastewater**

Wastewater will be discharged to the marine environment from the drilling rig, vessels and platform when manned during commissioning/start up, operational maintenance and planned shutdown activities. Wastewater consists of domestic sewage, greywater, bilge and deck drainage from open, un-contaminated drainage areas. The volume of treated sewage discharged is influenced by the number of personnel onboard the platform/vessel. In general, it is assumed that 0.5 $m^3$–1 $m^3$ per person per day will be released to the marine environment. When taking into consideration the typical POB of the platform (when manned) and project vessels, the sewage volume discharged is expected to range between approximately 14 $m^3$–120 $m^3$ per day.

**Cooling Water**

Cooling water discharges will not occur from the Crux platform. Air cooling has been selected as the medium for the NNM platform concept, therefore no continuous release of cooling water during operations will occur.

It may be expected that small volumes of cooling water (typically characterised as utility discharges) will be discharged from vessels, with volumes expected to be in the order of approximately 5,000 $m^3$–10,000 $m^3$ per day per vessel, depending on the type of vessel.

**Hydrotest Water**

Pressure-testing (or flood, clean, gauge and testing) is required to assess the structural integrity of subsea facilities, including flowlines, riser, spools and the export pipeline. Pressure-testing is undertaken by using treated seawater and internal pressures monitored to detect any leaks. Hydrotest water may consist of seawater containing combinations of the following constituents; biocides, corrosion inhibitor, scale inhibitor, dye, oxygen scavengers, MEG and gel slugs. Chemicals are required to avoid metal corrosion, prevent bacterial growth and the accumulation of scale on internal surfaces, all aimed at maintaining pipeline integrity.

The majority of the hydrotest water discharged will be associated with testing of the export pipeline. The export pipeline will be flooded with approximately 48,000 $m^3$ of treated seawater which will be released near the seabed at either the Crux platform or Prelude FLNG facility end of the export pipeline once pressure-testing activities are complete. The volumes of hydrotest water required for the rigid riser will be significantly smaller than that required for the export pipeline and are expected to be in the order of approximately 100 $m^3$. The volumes of hydrotest water required for all future subsea tie-backs would be expected to be an order of magnitude less than the Crux export pipeline volumes.

The topside facilities associated with the platform will be hydrotested to ensure structural integrity, with the activity occurring in either the overseas construction yard or proposed Crux platform location. However, if hydrotesting of the topside facilities is undertaken in the in-field development area, the volume of hydrotest water that would be discharged is expected to be in the order of approximately 500 $m^3$–1,000 $m^3$.

**Drill Fluids/Cuttings**

As summarised previously in **Section 5.6.2.1**, there will be small volumes of drilling fluids and cuttings discharged during drilling of the production wells.

If drilling is used to support the installation of the Crux platform foundations, drill cuttings will be discharged to the seabed at the platform location. It is estimated that in the order of 1,130 $m^3$ of drill cuttings per hole will be discharged during this activity. Up to 16 holes may be drilled for the platform foundations. Drill fluids (or calcite or silicate based stabilising agents) may be required as mitigation in case of hole instability during the Crux platform foundation drilling activity. Any drill fluids used during this activity would be discharged at the seabed. While an estimate of the volume of drill fluids that may be discharged is currently unknown, as the activity is still being defined, it is expected to be in the same order of magnitude as that discharged during the drilling of the foundation wells.

### 5.7.8 Waste Management

Hazardous and non-hazardous solid wastes (except drilling cuttings and fluids, sewage and putrescible waste) and recyclable materials will be removed from the project area and returned to shore for processing.

The waste management strategy for the project will be designed to optimise segregation of waste in the offshore location and to minimise contamination of recovered waste destined for recycling or disposal. All non-hazardous and hazardous solid waste will be managed in accordance with the relevant Waste Management Procedure and the vessels' Waste Management Plan/Procedure, and as detailed in activity-specific EPs.

### 5.7.9 Emergency Events

Emergency events are incidents that have the potential to trigger impacts that would otherwise not be anticipated during the normal and planned activities. The magnitude of impact from emergency events can be greater than the magnitude of potential impacts associated with routine operations, however the probability of an emergency event occurring is significantly lower.

A detailed discussion of the potential low probability spill scenarios that may occur during the project, and the potential impacts and risks, are provided in **Section 8.**

The project will implement a number of stringent measures to mitigate the risk and potential impacts associated with the unlikely event of an unplanned discharge to the marine environment, including elimination controls (wherever possible), engineering controls, planned maintenance, operational procedures and spill response preparedness measures.

## 5.8 Assessment of Alternatives

The potential for tie-back of Crux and other nearby reservoirs to Prelude FLNG was flagged as part of the Prelude environmental approvals (Shell 2009):

*'When the Prelude field pressure eventually does start to reduce, the decline in production rate is likely to be backfilled by tiebacks from other gas sources so that the FLNG facility can continue to operate efficiently at full throughput. Exploration is still underway but potential gas sources include the nearby Concerto field, the Crux field and the Libra field. Sufficient spare tie-in points have been allowed for potential future gas tiebacks. Such tiebacks are not included in the scope of this draft EIS and will be the subject of a separate environmental approvals process to cover their field development and connecting pipelines.'*

Following the grant of a retention lease for the in-field development area in 2013, feasibility assessments were commenced in 2014. After the completion of the Auriga West-1 exploration well in the in-field development area in 2015, Concept Select studies have focused on the backfill opportunities presented for the Prelude FLNG host.

These studies focused on selecting an option from a range of alternative for key decisions underpinning the overall development concept. The decision-making process was informed by a number of criteria across the Technical, Economical, Commercial, Organisational and Political spectrum.

The concept selection process used for the Crux project follows the competitive scoping framework developed within Shell. Competitive scoping calls for the identification and development of the minimum technical requirements and hence scope for a development concept. Whilst this minimum scoped concept is able to meet technical requirements, it is possible that additional scope elements may enhance value by mitigating operational or execution risks.

Using this framework, the potential value trade-offs for the Crux project were identified and grouped into decisions. These were ranked according to estimated impact and/or risk mitigation on the overall Crux project.

The decision quality of individual key concept decisions, as well as the integration across inter-dependent concept decisions are documented and form part or the overall integrated concept select decision. Review and challenge from appropriate stakeholders are a key part of this process.

A key consideration in the decision-making process are HSSE requirements. The overall Crux HSSE management strategy can be summarised as follows:

- a Crux HSSE Management Plan has been developed for the project. This sets out goals, strategies and roles/responsibility for the Crux team
- a Crux HSSE & SP Premises document has been developed which capture a minimum set of standards for the design of the project. These Premises will be refined or extended as a result of the formal Hazards and Effects Management Process (HEMP) to ensure risks to people, assets, community and the environment are tolerable and ALARP. This includes Contractor HSSE
- design standards have been used in concept development, including Shell design requirements. The Shell HSSE control framework guides the minimum, mandatory requirements for the project, and

- HAZID workshops have been conducted involving multidiscipline teams. The sessions have focused on key differentiators between the various concepts and findings incorporated in the project Hazard and Effects register.

A large proportion of HSSE risk management, inclusive of all critical HSSE risks identified, has been integrated into the decision-making process by assessment during the decision quality process. If the decision being taken may have an impact on high potential impact HSSE risks, the NOPSEMA Decision Framework is used to determine the decision context. In addition to safety studies, an initial assessment of the potential ESHIA was undertaken at an early stage. This preliminary evaluation helped to inform the scope and focus of key issues to be further assessed in this OPP.

A summary of the key alternative development concepts evaluated as part of Concept Select, is provided in the following sub-sections.

### 5.8.1 Host Type

The host type decision focused on the selection of the host type at the Crux location. The following host types were considered during the study:

- subsea tieback to Prelude FLNG facility
- greenfield FLNG facility
- fixed host types, including:
    - Platform, and
    - Tension Leg Platform (TLP)/Spar.
- floating host types, including:
    - Floating Production Storage and Offloading (FPSO), and
    - Semi-submersible.

The subsea tieback option and greenfield FLNG option were reviewed early during screening and determined to not be commercially or economically viable. A summary of this decision process is provided below:

**Subsea Tieback**

Several studies were conducted investigating the feasibility of a direct subsea tieback to the Prelude FLNG facility which would avoid the requirement for an offshore host at Crux. This is schematically shown in **Figure 5-9**.

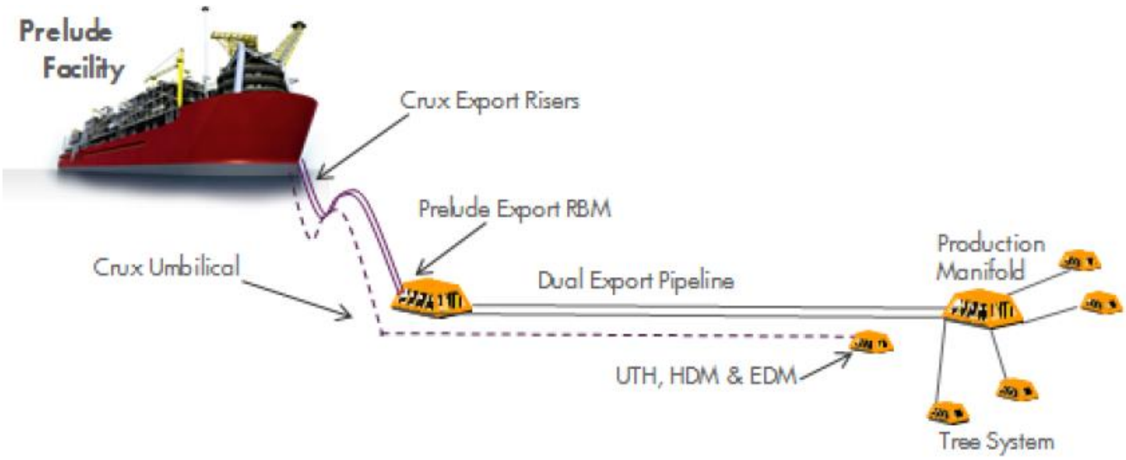



Figure 5-9: Crux Long Subsea Tieback Development Concept Evaluated during Early Screening

The concepts considered require a combination of novel technologies to mitigate several flow assurance issues. Although several novel technologies and other risk mitigation measures were possible within the subsea system, there remained a high overall technical and operational risk profile and at a non-competitive capital expenditure (CAPEX) position.

Of the decisions considered as part of the evaluation, the technical key showstopper for the overall concept was the issue of hydrate management. A range of management strategies were investigated but a feasible option could not be found:

- continuous MEG injection – would require replacement of an existing batch MEG Regeneration module with a continuous system at Prelude. The potential Prelude FLNG shutdown required for this project concluded it economically unattractive compared to alternative host type concepts.
- kinetic hydrate inhibitor – would require depressurisation of export pipeline after shut-in (approximately 150 million standard cubic feet of gas, > 24 hours flaring at the Prelude FLNG facility). Re-pressurisation of the pipeline for re-start is an issue. Limitations of water production would significantly impact gas recovery, impacting the overall economics of this option.
- green anti-agglomerate – requires technology development with timing uncertainty and low probability of success, and
- subsea water removal/dehydration – requires technology development with timing uncertainty and low probability of success.

Given a viable flow assurance strategy is not available for the subsea tieback concept, it was de-selected which confirmed the requirement for a Crux offshore host to, as a minimum, remove water for hydrate management.

**Greenfield FLNG Facility Option**

The greenfield FLNG facility development option showed there is insufficient resource base in the greater Crux area to support a standalone FLNG development given the capital expenditure requirements to pursue this option. Therefore, this was de-selected at an early stage and not carried further.

### Fixed and Floating Host Options

A range of offshore host types are available that were identified to be deployable at the Crux location. An initial screening was performed to narrow the host types to be focused on for the Crux opportunity. An outline of the key host types considered for Crux are shown in **Figure 5-10** (fixed) and **Figure 5-11** (floating), respectively. All host types are technically feasible but have inherent constraints highlighted in yellow.

The Fixed Platform concept was identified as the optimal host type for Crux. It provides inherently lower HSSE exposure and a higher capital efficiency than floating FPSO concepts.

Although a number of technical risks (such as soil uncertainty and drill execution) may be higher than FPSO concepts, mitigation plans have been identified and are in place.

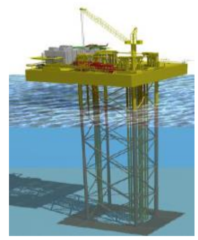
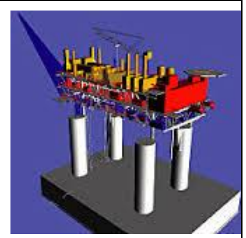
| | **TLP** | **Platform** | | |
|---|---|---|---|---|
| | | **Jacket** | **Shallow** | **Storage** |
| |  |  |  |  |
| Dry Tree Well | Potential | Yes | No | Yes |
| Liquid Storage | No | No | No | Yes |
| CAPEX | High | Low | Medium | High |

Figure 5-10: Fixed Host Types Screened for Crux

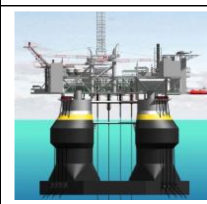
| | **FPSO** | | **Semi-sub** | |
|---|---|---|---|---|
| | Ship-Shaped | Sevan | Conventional | Ultra-Draft |
| |  |  |  |  |
| Dry Tree Well | No | No | No | Potential |
| Liquid Storage | Yes | Yes | No | No |
| CAPEX | Low | Low | High | Medium |

Figure 5-11: Floating Host Types Screened for Crux

In the context of relative environmental impact and risk, the following is concluded:

- all options present materially the same environmental impacts and risks with minimal differentiation between them
- the options which require the smallest physical host type (fixed jacket and shallow platforms) present the least overall footprint in terms of material use to build the facilities
- the fixed jacket platform has enabled a significant reduction (approximately 80%) in upstream combustion GHG intensity, compared to a floating FPSO concept, with limited onboard atmospheric emissions at the platform
- the fixed jacket platform (unmanned) has a limited ability to carry out complex water treatment, and
- the NNM platform provides a simple concept with minimal vessel movements once operational, and no requirement for cooling water discharge from the platform.

To provide a broad comparison of the merit of the different host types that were determined to be feasible for the Crux project, a qualitative assessment is presented in **Table 5-6**.

This reflects key considerations across safety, environment, technical, commercial and stakeholder/society expectations, which are taken into account by Shell as part the decision-making process in identifying the optimal host type concept appropriate to the field development.

Table 5-6: Qualitative Comparison of Feasible Host Types for the Crux Project

| Key Evaluation Criteria | Fixed Host Options | | | | Floating Host Options | | | |
|---|---|---|---|---|---|---|---|---|
| | Platform (premise case of NNM) | | TLP | | FPSO | | Semi-sub | |
| | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale |
| **Safety** | | | | | | | | |
| - HSSE exposure risk | 5 | Fixed platform has relatively lower HSSE exposure risk.<br>NNM platform has lowest HSSE risk, over operational lifetime. Individual Risk Per Annum and Potential Loss of Life are 50% lower for a NNM platform as compared to a manned platform | 4 | Fixed platform (TLP) has relatively lower HSSE exposure risk.<br>Marginally higher HSSE exposure risk with a manned TLP philosophy. | 2 | Higher HSSE exposure risk relative to fixed platform options. | 2 | Higher HSSE exposure risk relative to fixed platform options. |
| **Environment** | | | | | | | | |
| - Physical presence | 3 | Seabed disturbance anticipated to be broadly similar across host types - variable depending on seabed layout and configuration.<br>Platform requires piled foundations, but no anchoring.<br>All options require a subsea pipeline to facilitate Crux to be backfill to Prelude FLNG, therefore not a differentiating feature. | 3 | Seabed disturbance anticipated to be broadly similar across host types - variable depending on seabed layout and configuration. TLP requires the platform to be tethered to the seabed.<br>All options require a subsea pipeline to facilitate Crux to be backfill to Prelude FLNG, therefore not a differentiating feature. | 3 | Seabed disturbance anticipated to be broadly similar across host types - variable depending on seabed layout and configuration. FPSO host type requires a mooring system supported by anchoring.<br>All options require a subsea pipeline to facilitate Crux to be backfill to Prelude FLNG, therefore not a differentiating feature. | 3 | Seabed disturbance anticipated to be broadly similar across host types - variable depending on seabed layout and configuration. Semi-sub host type requires a mooring system supported by anchoring.<br>All options require a subsea pipeline to facilitate Crux to be backfill to Prelude FLNG, therefore not a differentiating feature. |
| - Vessel movements | 4 | NNM platform provides a simple host type concept with minimal vessel movements once operational, with limited maintenance visits. | 3 | Fixed platform (TLP) likely to have comparable vessel movements, although dependent on manned vs unmanned. | 2 | FPSO has potential for higher vessel movements, with offtake tankers (if offtake of condensate) and service support vessels. | 2 | Semi-sub likely to have comparable vessel movements, although dependent on manned vs unmanned. |
| - Light emissions | 5 | All offshore facilities and vessels must meet maritime and operational safety lighting requirements, regardless of host type.<br><br>NNM platform requires minimal lighting during operational lifetime, relative to other host type options. This is to reflect the not-normally manned status with the exception of maintenance visits. | 4 | All offshore facilities and vessels must meet maritime and operational safety lighting requirements, regardless of host type.<br><br>Fixed platform (TLP) likely to have comparable light emissions, although dependent on manned vs unmanned. | 3 | All offshore facilities and vessels must meet maritime and operational safety lighting requirements, regardless of host type.<br><br>FPSO likely to have greater light emissions compared to platform for a larger concept layout, but dependent on the lighting philosophy to meet functional requirements. | 3 | All offshore facilities and vessels must meet maritime and operational safety lighting requirements, regardless of host type.<br><br>Semi-sub likely to have greater light emissions compared to platform for a larger concept layout, but dependent on the lighting philosophy to meet functional requirements. |
| - Underwater noise | 4 | Underwater noise is anticipated to be broadly similar across host types - depending on the nature of primary sources. Short-term contribution from piling expected to be primary source, short-term and intermittent.<br><br>A NNM platform has relatively lower vessels during operations, therefore vessel-related noise is expected to be lower over the operational lifetime. | 3 | Underwater noise is anticipated to be broadly similar across host types - depending on the nature of primary sources. | 3 | FPSO host type likely to have higher vessel-related noise as a result of additional offtake tankers and service support vessels. However, unlikely to represent a material differentiator given the low contribution of vessel-related noise. | 3 | Underwater noise is anticipated to be broadly similar across host types - depending on the nature of primary sources. |
| - Atmospheric emissions | 5 | Fixed jacket platform has a significantly lower emissions intensity, compared to a floating concept, with limited onboard atmospheric emissions at the platform. | 4 | TLP has a lower emissions intensity, compared to a floating concept, with limited onboard atmospheric emissions at the platform. | 2 | FPSO has higher emissions intensity, requiring additional onboard power generation and compression utilities, compared to fixed host types. | 2 | Semi-sub has higher emissions intensity, requiring additional onboard power generation and compression utilities, compared to fixed host types. |
| - Invasive marine species | 3 | Risk of invasive marine species anticipated to be broadly similar across host types. | 3 | Risk of invasive marine species anticipated to be broadly similar across host types. | 3 | Risk of invasive marine species anticipated to be broadly similar across host types.<br>Potential for slightly higher IMS risk from higher vessel movements. However, given standard industry controls, these are unlikely to differ significantly between host types. | 3 | Risk of invasive marine species anticipated to be broadly similar across host types.<br>Potential for slightly higher IMS risk from higher vessel movements. However, given standard industry controls, these are unlikely to differ significantly between host types. |

| Key Evaluation Criteria | Fixed Host Options | | | | Floating Host Options | | | |
|---|---|---|---|---|---|---|---|---|
| | Platform (premise case of NNM) | | TLP | | FPSO | | Semi-sub | |
| | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale |
| - Liquid discharges | 2 | Fixed jacket platform (NNM) has a limited ability to carry out complex water treatment, with space restrictions. Additional equipment would be required, which increases complexity and maintenance requirements; this is not aligned with the NNM platform concept.<br>No requirement for cooling water discharge from the platform.<br>PFW discharge is dependent on the reservoir characteristics over the field life. Remote monitoring and response to off-specification PFW is a key consideration for a NNM platform concept, given the platform will be unmanned between maintenance shifts.<br>NNM platform has minimal sewage and greywater wastes during operation, with limited personnel on board relative to manned host type options.<br>Other liquid discharges (deck drainage, hydrotest, drilling fluids and cuttings, etc), not significantly influenced by host type. | 3 | Comparable liquid discharges, relative to other host types.<br>PFW discharge treatment options are more available in a larger manned facility, where space restrictions are less.<br>Other liquid discharges (deck drainage, hydrotest, drilling fluids and cuttings, etc), not significantly influenced by host type. | 3 | Comparable liquid discharges, relative to other host types.<br>PFW discharge treatment options are more available in a larger manned facility, where space restrictions are less.<br>Other liquid discharges (deck drainage, hydrotest, drilling fluids and cuttings, etc), not significantly influenced by host type. | 3 | Comparable liquid discharges, relative to other host types.<br>PFW discharge treatment options are more available in a larger manned facility, where space restrictions are less.<br>Other liquid discharges (deck drainage, hydrotest, drilling fluids and cuttings, etc), not significantly influenced by host type. |
| - Waste management | 4 | Fixed jacket platform (NNM) has minimal waste, including very low/negligible domestic wastes during operations. | 4 | Fixed platform (TLP) likely to have comparable waste management, although dependent on manned vs unmanned. | 3 | Waste management requirements typically expected to be greater for a floating FPSO concept, with greater volumes of hazardous and non-hazardous wastes to be handled, segregated and transferred. | 3 | Waste management requirements typically expected to be greater for a floating host concept, with greater volumes of hazardous and non-hazardous wastes to be handled, segregated and transferred. |
| - Emergency events | 3 | The nature and extent of emergency (unplanned) events, and the preventative control and response framework appropriate to the risk, are expected to be broadly similar across host types.<br>Credible spill volumes are influenced by the project-specific inventories and risk of release. Not expected to be a major differentiating factor across host types, on the basis that a multi-phase export pipeline from a NNM platform is transferring comparable volumes of gas and condensate, as alternative host types. Physical space restrictions on platform may limit the volume of liquids onboard, however the risk of uncontrolled release remains irrespective of host type. | 3 | The nature and extent of emergency (unplanned) events, and the preventative control and response framework appropriate to the risk, are expected to be broadly similar across host types.<br>Credible spill volumes are influenced by the project-specific inventories and risk of release. Not expected to be a major differentiating factor across host types. | 3 | The nature and extent of emergency (unplanned) events, and the preventative control and response framework appropriate to the risk, are expected to be broadly similar across host types.<br>Credible spill volumes are influenced by the project-specific inventories and risk of release. Not expected to be a major differentiating factor across host types. | 3 | The nature and extent of emergency (unplanned) events, and the preventative control and response framework appropriate to the risk, are expected to be broadly similar across host types.<br>Credible spill volumes are influenced by the project-specific inventories and risk of release. Not expected to be a major differentiating factor across host types. |
| **Technical** | | | | | | | | |
| - Soil stability | 3 | A platform concept is more dependent on suitable soil conditions than a floating host type, for the platform foundation design. Suitability informed by geotechnical studies. | 3 | A platform concept is more dependent on suitable soil conditions than a floating host type. | 4 | Floating concept less dependent on suitable soil conditions, though important for anchoring system. | 4 | Floating concept less dependent on suitable soil conditions, though important for anchoring system. |

| Key Evaluation Criteria | Fixed Host Options | | | | Floating Host Options | | | |
|---|---|---|---|---|---|---|---|---|
| | Platform (premise case of NNM) | | TLP | | FPSO | | Semi-sub | |
| | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale | Relative Evaluation | Rationale |
| - Drill execution strategy (dry tree wells) | 4 | A fixed jacket platform concept can accommodate the intended drill execution strategy for dry tree wells. | 3 | A fixed jacket platform concept can accommodate the intended drill execution strategy for dry tree wells.<br>TLP platform has technical complexities, relative to a fixed jacket platform. | 2 | Drilling execution strategy for dry tree wells cannot be readily accommodated in an FPSO concept. | 2 | Drilling execution strategy for dry tree wells cannot be readily accommodated in a semi-sub concept. |
| - Liquid storage | 2 | Liquid storage requirements are constrained with a platform concept, with physical space restrictions compared to FPSO host type. | 2 | Liquid storage requirements are constrained with a platform concept, with physical space restrictions compared to FPSO host type. | 4 | Liquid storage requirements can be readily accommodated with an FPSO concept, with typically larger offtake and storage capacity. | 2 | Liquid storage requirements are constrained with a semi-sub concept. |
| **Commercial** | | | | | | | | |
| - CAPEX | 4 | Low-medium CAPEX relative to other host type options – variable depending on platform type. NNM platform provides a cost-competitive option for the field development. Higher capital efficiency than FPSO host type. | 2 | High CAPEX relative to other host type options. | 3 | Low-medium CAPEX relative to other host type options.<br>Lower capital efficiency than NNM platform host type. | 2 | Medium-high CAPEX relative to other host type options. |
| **Society/Stakeholder** | | | | | | | | |
| - Societal expectations | 3 | Societal expectations for the safe, responsible commercialisation of gas resource, with HSSE&SP commitments, expected to be the same, irrespective of host type. | 3 | Societal expectations for the safe, responsible commercialisation of gas resource, with HSSE&SP commitments, expected to be the same, irrespective of host type. | 3 | Societal expectations for the safe, responsible commercialisation of gas resource, with HSSE&SP commitments, expected to be the same, irrespective of host type. | 3 | Societal expectations for the safe, responsible commercialisation of gas resource, with HSSE&SP commitments, expected to be the same, irrespective of host type. |

| Relative Evaluation | Descriptor |
|---|---|
| 1 | Significantly worse outcome |
| 2 | Marginally worse outcome |
| 3 | No difference |
| 4 | Marginally better outcome |
| 5 | Significantly better outcome |

**Export Pipeline Configuration**

The hydrocarbon export system configuration decision focused on selecting the products to be exported and hence the processing requirements on the Crux platform. The following alternatives were considered:

- multiphase – gas and condensate exported in a single pipeline
- rich gas and condensate – non-hydrocarbon dewpointed gas in a pipeline and stabilised condensate in a separate pipeline. This option was found to have no appreciable benefits to the multiphase pipeline behaviour and as such was discounted
- dry gas and condensate – hydrocarbon dewpointed gas in a pipeline and stabilised condensate in a separate pipeline
- dry gas – hydrocarbon dewpointed gas in a pipeline, no liquid pipeline. This option requires liquid storage at the Crux platform and as such has been discounted due to the capital-intensive nature of introducing storage for the platform concept, and
- supercritical – high pressure multiphase pipeline that enables a single, dense phase stream. Discounted due to impractical high pressures required and consequences on compression at Crux, pipeline design pressure, safeguarding and low temperature issues at Prelude.

A comparison of the topsides processing systems required to support the options considered for the platform are shown in **Table 5-7**.

Table 5-7: Comparison of Topsides Processing Systems Required to Support Export Pipeline Options Evaluated for Concept Select

| Export Pipeline System Configuration | Gas Dehydration | Gas Hydrocarbon Dewpointing | Export Compression | Condensate Pump | Pipeline(s) |
|---|---|---|---|---|---|
| Multiphase | TEG dehydration | None | None | None | 1x26" Multiphase |
| Dry gas and condensate | TEG dehydration | Valve and cold separator | Export compressor at Crux | Booster pump required | 1x26" Dry Gas and 1x8" Condensate |

The risks associated with multiphase flow and the impact it has on the Prelude FLNG facility were assessed using Dynamic Flow Assurance and Dynamic Process simulation tools. These concluded that the risks are manageable.

Minor modifications to the Prelude FLNG facility high pressure separator to increase the liquid surge capacity and liquid drain rate are able to be readily implemented, to provide an additional margin to handle liquid surges from the multiphase pipeline.

The dry gas and condensate export configuration eliminates the risk associated with liquid management at the Prelude FLNG facility in regard to liquid surges. However, this option introduces significant scope to the Crux platform topsides. These are both capital intensive and it puts greater demand on maintenance and increases the risk that the NNM philosophy for the platform could not be achieved.

As the risks associated with the multiphase pipeline are manageable and the associated downtime with liquid management not material compared to the CAPEX associated with the dry gas and condensate export configuration it was decided that the platform will have a single multiphase export configuration.

In the context of relative environmental impact and risk, the following is concluded:

- a single multiphase pipeline provides for a smaller seabed disturbance footprint
- inherently low risk of emergency events through preventative controls and integrity maintenance regime, and
- provides best pipeline integrity outcome compared with other options.

#### 5.8.1.1 Manned versus Unmanned Platform Concept

The decision for the selection of the manning philosophy for the Crux platform gave consideration to the optimum combination of capital efficiency and personnel risk exposure.

The processing facilities required for the platform-based concept are significantly reduced compared to the FPSO concept. Simplification of the topsides facilities and associated reduction in maintenance requirements and manhours provides the opportunity to operate the platform remotely while maintaining the facilities on a campaign maintenance basis.

The following manning philosophies were considered:

- NNM platform operated remotely from the Prelude FLNG facility or Perth with campaign maintenance one week in every six weeks and up to 12 weeks with 14 POB. Reduced facility NNM living quarters and no kitchen facilities
- lighthouse manning platform operated remotely from the Prelude FLNG facility or Perth with a minimum permanent maintenance crew of around nine personnel. Provision of full living quarters and permanent kitchen facilities
- permanently manned and operated platform with a permanent operations/maintenance crew of 14 personnel. Provision of full living quarters with permanent kitchen facilities
- NNM manning-ready platform operated remotely from the Prelude FLNG facility or Perth with campaign maintenance one week in six weeks with 14 POB, but with capability to be permanently manned/operated in future if required. Provision of contingent space for expansion of the living quarters (kitchen, common areas)
- NNM with no permanent accommodation and vessel transfer of personnel (walk-to-work only), and
- fully unmanned with minimum frequency campaign maintenance (approximately once per year).

In order to confirm feasibility for NNM operations, an assessment of the feasibility of remote operations has been carried out and a maximum no-touch-time of 3 months is achievable for the equipment.

From a personnel risk perspective, it was demonstrated that Individual Risk Per Annum and Potential Loss of Life are 50% higher for a manned platform as compared to a NNM platform. A significant overall value benefit for the NNM platform versus manned was also derived. This fact, in conjunction with the significant reduction in personnel risk, justified the selection of the NNM platform option. It was recognised that full definition during FEED and Detailed Design phases of the project is required to ensure the platform design, equipment specification and selection and platform operability (remote start of wells, gas turbine generators, PFW treatment adaptive management response, etc.) meets the more stringent requirements for a NNM platform.

Shell undertook a comparative assessment of the manned and NNM platform concepts to determine which platform concept is preferred. Shell identified a hierarchy of criteria and sub-criteria that were assessed during the comparative assessment (**Figure 5-12**). The comparative assessment considered each of the criteria, sub-criteria and alternatives, which were aggregated to determine the overall relative preference for the manned and NNM platform concepts. The comparative assessment process captured the opportunity cost of selecting the manned or NNM platform concepts for each of the sub-criteria. Weightings for all criteria and sub-criteria are shown in **Figure 5-12** and summarised in **Figure 5-13**.

The NNM platform concept was determined to be the preferred concept for all criteria and was clearly the preferred concept when considering the safety and cost criteria and sub-criteria (**Figure 5-13**). Differences between the manned and NNM concepts were less pronounced in the other criteria and sub-criteria, however the NNM concept was preferred in each. The context for the deliberations during the comparative assessment of the criteria and sub-criteria are summarised in the following sections. Important benefits of the NNM platform concept include:

- significantly reduced health and safety risk profile for employees and contractors through reduced hours worked offshore and reduced need for crew transfers
- reduced operational costs through lower manning requirements and relative simplicity of the NNM platform, and
- maintained use of the existing Prelude FLNG facility.

The selection of the NNM concept represents a trade-off of some opportunities that may be available for a manned platform, however the comparative assessment determined that the NNM was the most preferred platform concept. Opportunities that were not realised included:

- on-site storage of condensate, which requires greater processing and stabilisation of hydrocarbons at the Crux field. This processing, along with condensate offtake activities, would require manning of the platform. Condensate storage would typically require an additional platform in the Crux in-field development area, such as a floating storage and offtake facility. This additional platform would result in additional environmental impacts and risks, however it would also remove condensate transport via the Crux export pipeline,
- tertiary treatment of PFW prior to discharge to the sea. This would require more complex processing and ancillary systems (e.g. steam generation), which would require the platform to be manned. PFW re-injection was not feasible for both a manned and NNM platform concept due to the lack of a suitable reservoir being identified (refer to **Section 5.8.2** for further discussion), and
- slightly improved ability to detect small hydrocarbon leaks onboard the Crux platform.

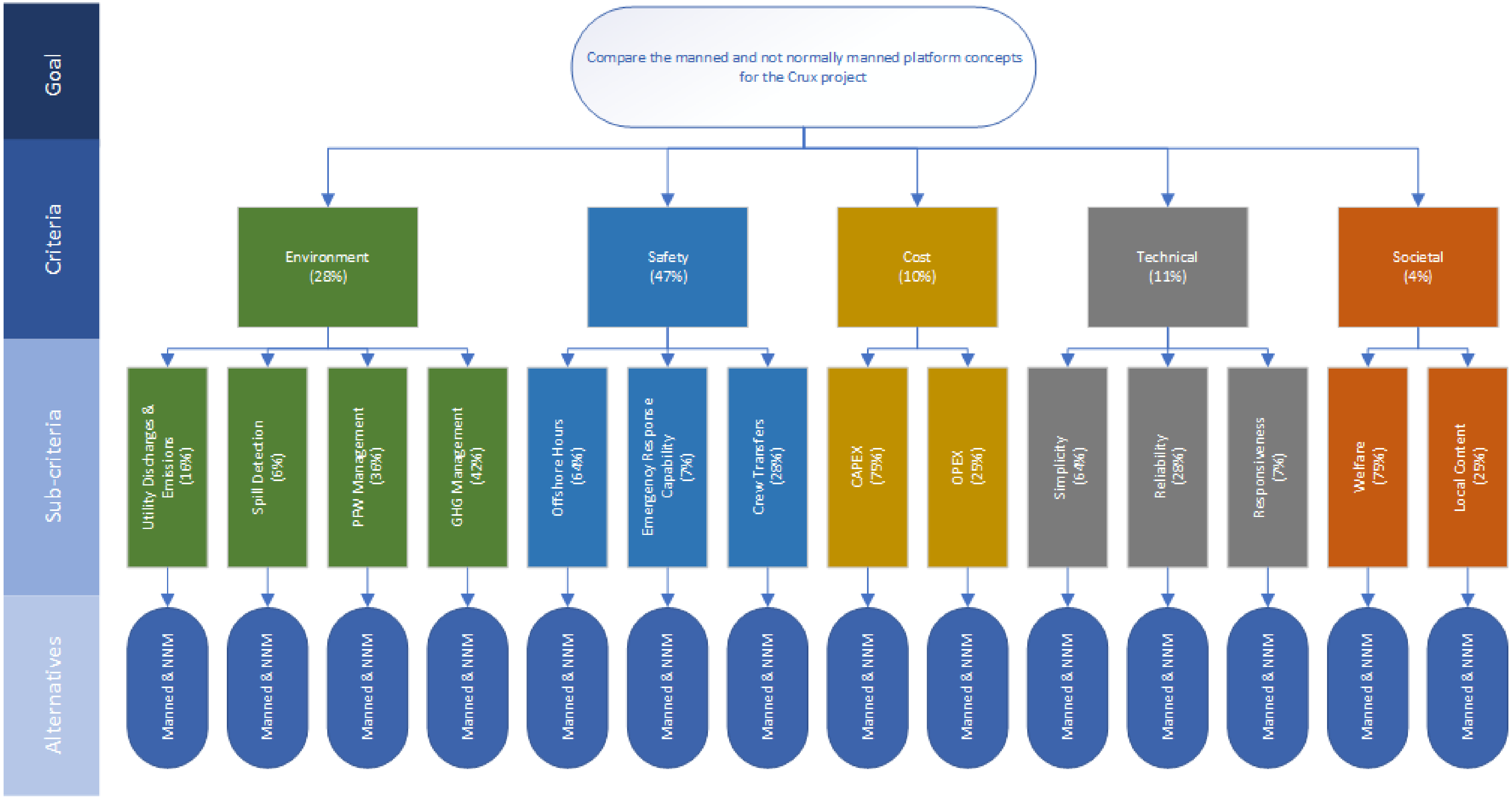



Figure 5-12: Manned and NNM Comparative Assessment Hierarchy with Weightings in Brackets

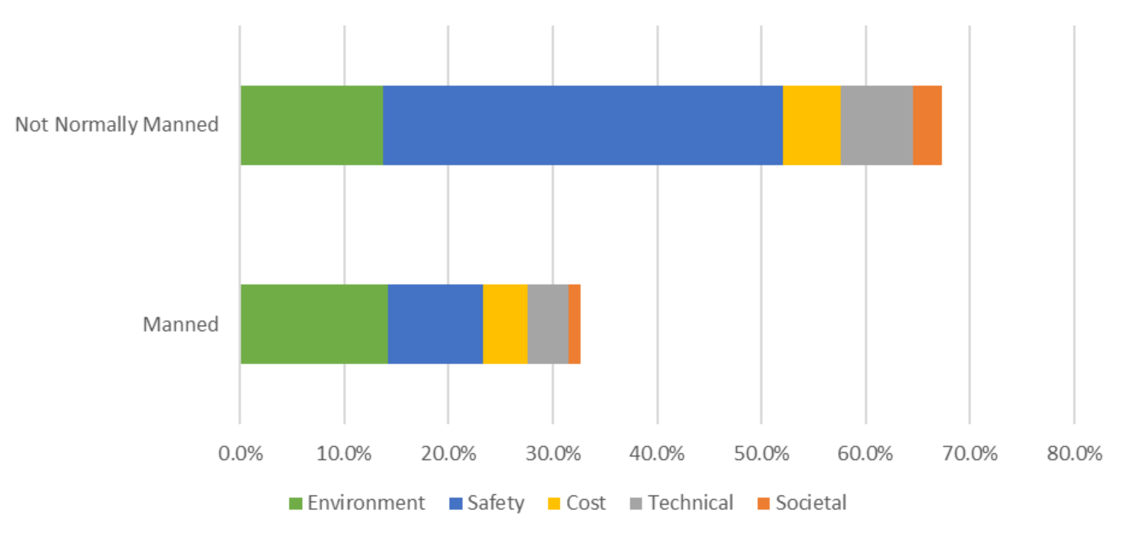



Figure 5-13: Aggregated Results of Manned and NNM Comparative Assessment

**Safety**

Safety is always a critical concern onboard offshore oil and gas facilities. Shell has a strong desire to reduce personnel exposure to safety risks offshore, which is the key driver for Shell's preference for the NNM platform concept. As a result, the outcomes of the comparative assessment of safety were weighted high relative to other criteria.

Sub-criteria considered within the safety criterion, in order from most important to least important, were:

1. offshore hours
2. crew transfers, and
3. emergency response.

*Offshore Hours*

The NNM platform concept will result in considerably fewer hours spent offshore by personnel. This results in considerably fewer opportunities for personnel to be exposed to health and safety risks. Offshore oil and gas industry statistics clearly show a strong correlation between the hours worked offshore and the number of health and safety incidents. Hence, the considerable reduction in hours worked offshore for an NNM platform compared to a manned platform yields a significant safety benefit to employees and contractors.

The NNM platform concept is very strongly preferred to a manned platform concept due to significantly fewer hours being worked offshore.

*Crew Transfers*

Given the offshore location of the Crux platform, routine crew transfers for the platform would be by helicopter. An NNM platform concept requires fewer helicopter transfers than a manned platform, thereby resulting in a commensurate reduction in safety risk.

On this basis, the reduced number of helicopter transfers required for an NNM platform yields a clear safety advantage over a manned platform concept.

*Emergency Response*

Neither a manned or NNM platform will have advanced emergency response facilities (e.g. emergency room and trained personnel) onboard. While both manned and NNM platforms have basic first aid facilities and personnel, the emergency response for any serious incident onboard both manned and NNM platform concepts would be to evacuate any injured persons from the platform and transport them to the nearest suitable treatment facility, typically by helicopter.

As such, neither a manned nor an NNM platform concept has an advantage in terms of emergency response, both concepts are equally preferred based on this sub-criterion.

**Environment**

Within the environment criterion, a series of four sub-criteria were identified and compared. These are listed below:

1. GHG management
2. PFW management
3. utility discharges and emissions, and
4. spill detection and response.

*GHG Management*

As outlined above in **Section 5.8.1**, the platform concept has a significantly lower emissions intensity in comparison to a floating (i.e. FPSO) concept, with limited onboard atmospheric emissions at the platform.

The greatest potential reduction in GHG emissions from the Crux project is through the implementation of carbon capture and storage (CCS). CCS was deemed not to be feasible for the Crux project.

Unlike an NNM platform, a manned platform would require continuous additional power generation to provide for crew utilities onboard the Crux platform. Emissions from utilities such as power generation are considered below in **Utility Discharges and Emissions**. Other potential GHG emissions, such as fugitive emissions and flaring, will be similar for manned and NNM platform concepts.

On this basis, both platform concepts are roughly equivalent; neither is the preferred option in relation to GHG management.

*Utility Discharges and Emissions*

Utility discharges and emissions (excluding PFW, refer to **PFW Management** below) from an NNM platform will comprise mainly exhaust emissions from the onboard gas turbine generators that power the platform. Utility discharge streams associated with manning, such as sewage, putrescible wastes and grey water, will only occur when the platform is manned (e.g. during maintenance visits). Power consumption on an NNM platform will increase during periods when the platform is manned due to the use of utilities (e.g. heating, ventilation and air conditioning, refrigeration etc.). Unlike the NNM platform concept, all of these discharges and emissions will continuously be released by a manned platform during routine operations. Hence, the routine emissions and discharges from a manned platform are expected to be considerably greater than an NNM platform.

A manned platform will require routine external lighting of the platform to maintain a safe working environment. An NNM platform would only require such lighting when manned; during NNM when not manned an NNM platform would only require sufficient lighting for safe navigation requirements. A manned platform will generate artificial light for longer periods of time, with proportionally greater potential for environmental impacts from artificial lighting.

Based on the above points, the NNM concept was the preferred concept when assessed on the utility discharges and emissions sub-criterion.

*PFW Management*

The preferred PFW treatment and disposal system for the NNM platform is primary treatment via the produced water degasser vessel prior to discharge from the platform, as detailed in the comparative assessment in **Section 5.8.2**. Treatment of the PFW on the Crux platform prior to disposal to the environment was the only feasible treatment and disposal method identified. Re-injection and treatment/disposal at other facilities (Prelude, which is approximately 160 km north-east of the Crux platform, or Montara, located approximately 36 km north of the Crux platform) were determined to be not feasible for both manned and NNM concepts.

The use of an NNM platform precludes the use of relatively large and high maintenance PFW treatment systems, such as macro-porous polymer extraction (MPPE), which typically require a range of supporting services (e.g. steam generation, deionised / distilled water, storage tanks etc.). Such treatment systems may be feasible on a manned platform, where additional space and maintenance personnel are available. As such, a manned platform may result improved environmental performance in removing hydrocarbons from the PFW stream compared to an NNM platform. However, as discussed in **Section 5.8.2**, the expected improvement in performance was not considered to be significantly better than primary treatment only.

A manned platform was identified has potentially having improved PFW treatment compared to an NNM platform. However, a manned platform was identified as having considerable other safety, environmental, cost, technical and societal disadvantages. These disadvantages outweigh the minor environmental benefit of potentially improved PFW treatment.

*Spill Detection*

Detecting a hydrocarbon spill is critical in undertaking a spill response. Large-scale hydrocarbon releases are typically very easy to detect within the control room of an NNM platform due to their effects (e.g. rapid drop in pressure in process equipment, vapour detection alarms etc.). Small hydrocarbon leaks may be much more difficult to detect on an NNM platform; however, the potential environmental impacts are also commensurately small. Note that a large hydrocarbon release typically requires the platform to be evacuated. Once evacuated, a platform is effectively unmanned regardless of whether it typically manned or not, mitigating any advantages of a manned platform of an NNM platform in spill detection and response. Operational experience indicates that spills that have the potential to result in detectable impacts to the environment are very uncommon.

A manned platform concept would enable on-site storage of condensate to be considered as a feasible host type (e.g. a floating storage and offtake facility connected to the Crux platform). On-site condensate storage is not considered feasible for a NNM platform concept due to the additional processing, stabilisation and cargo offloading needed, which would require manning of the facilities. On-site condensate storage would eliminate the transport of hydrocarbon liquids via the export pipeline, which may reduce the environmental risk of a leak from the pipeline. However, it would introduce the storage and transfer of large volumes of hydrocarbons at the on-site condensate storage facility in the Crux in-field development area. This introduced the risk of condensate spills during offtake operations or from a structural failure of the on-site condensate storage facility. Hence on-site condensate storage does not eliminate the risk of a condensate leak, it transfers the risk from the export pipeline to the on-site storage facility.

The condensate inventory of the export pipeline is estimated to be a maximum of 1–2 days of production at any one time. An on-site condensate storage facility would typically have a condensate inventory of up to 40 days of production when nearing capacity (e.g. immediately prior to an offtake). Hence, a worst case release from the on-site condensate storage facility may result in considerably greater liquid hydrocarbon released to the environment than the gas and condensate export pipeline. Subsequently, on-site condensate storage is not considered to provide any improvement of spill risk management compared to the gas and condensate export pipeline; in some scenarios on-site condensate storage poses greater environmental risk (e.g. a worst-case release from the on-site condensate storage facility).

A range of measures are routinely implemented on both manned and NNM platforms to reduce the likelihood of spills reaching the environment, such as containment around liquid hydrocarbon storage tanks and hazardous drains designed to divert liquid hydrocarbon releases away from the environment (e.g. to slops tanks, oily water separators etc.). Many such design features are passive (i.e. they operate continuously and do not require activation) and are effective regardless of whether a platform is manned or NNM. Additional measures may be used on NNM platforms to assist in detecting spills, such as satellite monitoring of the Crux platform location. Feasible design and monitoring controls that will assist with the early detection of spills or leaks from the Crux platform will be assessed during detailed engineering.

Small spills are more likely to be detected on a manned platform compared to an NNM platform; however, these spills may be prevented from reaching the sea due to passive platform design features and are expected to be of negligible environmental consequence. Large spills are expected to result in the evacuation of the platform and managed by the platform control room onboard the Prelude FLNG facility; there is expected to be no difference in the environmental performance of a manned or NNM platform in relation to large hydrocarbon spills.

Based on the above points, a manned platform is marginally preferred to an NNM platform when assessed on the spill detection sub-criterion.

**Cost**

The cost criterion considers the money expended on the Crux project during all phases of the project. These were broadly split into two categories, which were used as sub-criteria within the cost criterion:

1. CAPEX, and
2. operational expenditure (OPEX).

*CAPEX*

CAPEX for the construction and decommissioning of the Crux platform was determined to be comparable for manned and NNM platform concepts. Therefore, on this basis, the manned and NNM platform concepts were comparable when assessed on the CAPEX criterion.

*OPEX*

OPEX for the ongoing operation and maintenance of the NNM platform concept is lower than the manned platform concept. This is due to the reduced level of staffing required (i.e. remote control room staff only for the NNM concept compared to a platform based crew for the manned concept) and subsequent saving in staff costs.

On this basis, the NNM platform concept has a clear OPEX advantage over a manned platform concept.

**Technical**

The technical criterion considered the technical performance of a manned platform compared to an NNM platform. Direct technical comparisons between a manned and an NNM platform are difficult, as a manned platform would typically have additional processing equipment onboard in order to utilise the capability provided by the platform crew.

The sub-criteria within the technical criterion that were used to compare manned and NNM platform concepts, in order of decreasing importance, were:

1. simplicity
2. reliability, and
3. responsiveness.

*Simplicity*

NNM platforms tend to be simpler than manned platforms in order to reduce maintenance requirements and the likelihood of mechanical failures. Whilst manned platforms may also be of simple design, this would reduce the one of the key benefits of a manned platform – the platform crew can maintain more complex equipment, such as additional processing equipment.

Based on the simplicity sub-criterion, the NNM platform concept is preferred to a manned platform.

*Reliability*

The reliability sub-criterion is related to the simplicity sub-criterion; a simple platform is likely to be more reliable compared to a complex platform. As summarised above, the NNM platform concept will be simpler than a manned platform, and hence is likely to be less prone to breakdowns.

While a manned platform concept is likely to be more complex, and therefore inherently more prone to breakdown, a manned platform also has a higher capacity to undertake routine inspection and maintenance work, which compensates the potential decrease in reliability. As such, a manned platform is likely to be more reliable (e.g. have a lower proportion of downtime) than an NNM platform.

As such, a manned platform is preferred to an NNM platform based on the reliability sub-criterion.

*Responsiveness*

Responsiveness considers the ability for the platform to respond to potential faults or process upsets. A NNM platform is typically controlled remotely from a control room. Consequences of not being able to respond may include reduction or suspension of production from the platform. The actions that can be undertaken from the control room are constrained by the facility design; any technical issues that cannot be resolved remotely may require the mobilisation of a crew to the platform to undertake the work. This may require several days to plan and undertake.

A manned platform has the ability to respond to technical faults and process updates much more rapidly as personnel are already on site. However, any issues that require parts or equipment not available on the platform will require a similar timeframe to the mobilisation of a crew to the platform.

A manned platform would be more responsive than an unmanned platform and hence is preferred when assessed on this sub-criterion.

**Societal**

The societal criterion considered societies views more broadly. The sub-criteria considered within this criterion were:

1. welfare, and
2. local content.

*Welfare*

The welfare sub-criterion considered the general health and wellbeing of the personnel working on the Crux platform. The confined, isolated offshore platform environment presents some challenges for personnel, including extended periods away from their families and friends, isolation and relatively confined spaces compared to larger offshore facilities or onshore working environments. These conditions can have a range of effects on employees and their families, including impacts to mental and physical health.

An NNM platform will primarily be operated by crew onboard the Prelude FLNG facility, which is a large, modern offshore facility with excellent amenities for the crew, with periodic maintenance visits of relatively short duration. Conversely, a manned platform would require the crew to stay aboard the Crux platform, which is unlikely to be as well equipped as Prelude due to the smaller crew numbers and space constraints of the production platform.

On this basis, an NNM platform is the preferred platform concept, as it is likely to result in better welfare outcomes for Shell employees.

*Local Content*

The local content sub-criterion considers the opportunities for Australian businesses and citizens to benefit by provides goods and services to Shell. Shell is committed to engaging local content and is progressing an AIP for the Crux project. The design, construction and decommissioning phases of the Crux platform do not significantly differ between manned and NNM platform concepts. The main differences is during the operations phase, where an NNM platform will require fewer employees than a manned platform. Note that an NNM platform will still require crew for the Prelude FLNG facility control room, along with maintenance personnel for maintenance visits.
The manned platform concept is slightly preferred to an NNM platform when considering the local content sub-criterion.

### 5.8.2 PFW Treatment and Disposal Alternatives

For the Crux platform concept there will be a combination of initially condensed and, in later field life, condensed and formation water which is required to be disposed of. Shell identified a range of PFW treatment and disposal alternatives that are currently used in the offshore oil and gas industry. Alternatives were identified through reviewing existing PFW disposal options used within Shell and the offshore oil and gas industry more broadly.
The following list of PFW treatment and disposal alternatives were identified:

- reinjection at the Crux platform
- discharge to the sea via Prelude FLNG or Montara FPSO
- discharge to the sea at the Crux platform following treatment using a variety of potential processes:
  - primary treatment
  - secondary treatment
  - tertiary treatment
  - implementation of a buffer tank onboard the Crux platform for temporary storage of off specification PFW.
- post-treatment discharge to the sea at the Crux platform via:
  - above sea surface discharge from discharge pipe
  - below sea surface discharge from caisson

Each of these disposal options was examined to determine if it was feasible in the context of the NNM Operating Philosophy. This host type drives the need for simple, high reliability equipment, with the facility being unmanned apart from planned maintenance activities 3-4 times per year. Therefore, in the context of this evaluation of alternatives, feasibility is premised on the NNM basis of design. Disposal options that were determined not to be feasible were eliminated from further consideration. Descriptions and an assessment of the feasibility of each identified alternative are summarised in the **Option Feasibility Screening** section below.

Following the feasibility assessment, each of the feasible disposal options were then compared qualitatively using the following criteria:

- safety
- environmental
- technical feasibility, and
- cost (both capital and operational cost).

Considerations of each of these disposal options are summarised below in the **Feasible Option Comparison** section. Secondary treatment, of PFW with some treatment redundancies, and discharge above the surface at the Crux platform was determined to be the preferred disposal option when considering all the decision criteria.

### 5.8.2.1 Option Feasibility Screening

The feasibility of the identified PFW treatment and disposal alternatives considered the compatibility with the NNM platform operating philosophy. These considerations are summarised below.

#### Reinjection

Re-injection of PFW involved pumping PFW into a suitable geological reservoir using dedicated water injection wells. Re-injection typically significantly reduces the volume of PFW discharge to the environment. Discharges to the environment when implementing a re-injection system typically only occur when the system is not available (e.g. maintenance, equipment failure) or the rate of PFW production exceeds the injection capacity.

The environmental benefit of injection wells is somewhat negated by the fact they are notoriously unreliable. Contingency options, such as storage in buffer tanks or discharge to sea, are required to maintain production in the event the re-injection system is unavailable. Buffer tanks with sufficient volume to temporarily store PFW during outages is not feasible given the volumes of PFW that may be produced, the space constraints on the platform and the potential timeframes required to mobilise crew to the platform to reinstate the re-injection system.

In order to undertake re-injection, a suitable geological formation must be identified. This may include the reservoir that is producing hydrocarbons, or a non-producing formation that has the capacity to receive the PFW.

Re-injection into the production reservoir that is producing hydrocarbons may be an option, but this poses risks to reservoir integrity such as souring, scaling and formation damage. These may result in increased safety risks, increased chemical usage and reduced production. Injection into production reservoirs may be done to enhance hydrocarbon production (e.g. waterflooding for oil reservoirs); this method is not technically feasible for the Crux gas and condensate fields. PFW can be treated to improve its characteristics and reduce the risk to reservoir integrity, however these treatment systems require considerable space and maintenance, which is not consistent with the Crux NNM platform operating philosophy.

Non-producing geological formations were also considered which would reduce the risk to hydrocarbon reservoirs. Scaling and formation damage are still potential issues that typically require water processing at the platform topsides and chemical use to mitigate. Based on a review of the available subsurface data, no suitable non-hydrocarbon containing geological formation within the Crux area was identified that could be used to contain the re-injected PFW.

Considering these factors, a suitable geological formation with the capacity to receive PFW volumes generated during the Crux project has not identified.

Even if a formation was identified, re-injection requires additional dedicated injection wells. These impose further costs and environmental risks and impacts to drill, complete, operate and decommission. Additional equipment, such as water treatment, injection pumps and chemical storage tanks, is required onboard production facilities that have re-injection systems. This increases complexity and maintenance requirements.

Based on the discussion above, re-injection of PFW for the Crux project is not considered feasible because:

- the Crux NNM platform basis of design significantly limits the space available for equipment required for re-injection, such as water treatment, pumps and chemical storage.
- the Crux NNM platform concept delivers significant operational safety benefits through reduced personnel time on the platform. Operation of a re-injection system would likely require the platform to be manned and would increase maintenance requirements.
- re-injection into the Crux production reservoir poses risks to reservoir integrity and hydrocarbon recovery. Methods to mitigate reservoir risks by increased treatment of the PFW are not consistent with the Crux NNM platform operating philosophy.
- no suitable geological formations for re-injection that do not hold potentially commercial hydrocarbons have been identified within the Crux in-field development area.

Disposal of PFW by re-injection is not feasible for the Crux project and has not been considered further.

**Discharge via Prelude/Montara**

Transporting PFW to either the Prelude or Montara production facilities was investigated, both of which discharge treated PFW to the sea. Transport of PFW to other facilities would require the installation of a dedicated subsea pipeline. Given both Prelude and Montara discharge treated PFW to the sea, discharge of PFW at either of these facilities would not eliminate the risk of PFW. However, both Prelude and Montara have the capacity to store off-specification (i.e. high oil content) PFW, which the NNM Crux platform does not have. Off-specification water may be recirculated through the PFW treatment systems prior to discharge or blended to relatively low oil content PFW to meet the required PFW discharge standards. Neither Prelude nor Montara have been designed to receive PFW from the Crux project; sending PFW form Crux to these facilities may reduce their production capacities.

The PFW treatment systems at Prelude include tertiary treatment which may be expected to exceed the environmental performance of secondary treatment systems that are the preferred PFW treatment options for the Crux NNM platform. The treatment system at Montara is similar to the most preferred system on the Crux NNM platform. Hence, it is not considered to provide any improvement in environmental performance over discharge at the Crux platform.

Transport of PFW to either Prelude or Montara imposes technical flow assurance issues, including pipeline corrosion and hydrate formation. Management of these issues would require additional equipment such as pumps and chemical storage/injection systems on the Crux platform. This equipment would require additional maintenance and space on the platform, which is not consistent with the Crux platform NNM basis of design.

Based on the above, disposal of PFW via another facility is not considered feasible because:

- the Crux NNM platform basis of design significantly limits the space available for equipment required for PFW flow assurance, such as pumps and chemical storage.
- the Crux NNM platform concept delivers significant operational safety benefits through reduced personnel time on the platform. Operation of a PFW transport pipeline may require the platform to be manned and would increase maintenance requirements.

Disposal of PFW at Prelude or Montara is not feasible for the Crux project and has not been considered further.

**PFW Treatment at Crux Platform**

Several PFW treatment options were considered for the Crux platform. These have been categorised into the following:

- Bulk separation – gravity separation of the bulk water and condensate streams. For the Crux NNM platform, a liquid/liquid separator will be used to remove floating oil and entrained oil droplets (> 30 µm) from the PFW. With the Crux operating conditions, this is expected to reduce the oil-in-water content to less than 300 mg/L.
- Primary treatment – primary water treatment is designed for the removal of large hydrocarbon droplets, large solid particles and hydrocarbon slugs from the water stream, and can be designed to provide a stable feed to the subsequent water treatment stages by absorbing flow surges. Typically primary water treatment can tolerate 1,500 mg/l dispersed oil-in-water. The product stream of the primary water treatment step achieves typically <100 mg/l dispersed oil-in-water. Provided the droplet size distribution and other water characteristics are within the operating envelope of the equipment, primary water treatment can be sufficient to reduce the dispersed oil-in-water content to typical offshore discharge level of 30 mg/l.
- Secondary treatment – typically secondary water treatment can tolerate 100-300 mg/l dispersed oil-in-water and 50–100 mg/l total suspended solids (TSS). The product stream of the secondary water treatment step achieves typically <50 mg/l dispersed oil-in-water and <25 mg/l TSS.
- Tertiary treatment – typically tertiary water treatment can tolerate 50 mg/l dispersed oil-in-water and 25 mg/l TSS. The product stream of the tertiary water treatment step achieves typically 10–20 mg/l dispersed oil-in-water and <10 mg/l TSS. Equipment used to remove dissolved hydrocarbons, guard applications and hydrogen sulphide removal also falls in this category.

**Primary Treatment**

Primary treatment removes floating oil and entrained oil droplets (> 30 µm) from the PFW. Primary treatment relies on physical separation via the difference in density between the hydrocarbon droplets and the PFW.

Primary treatment systems do not rely on chemicals to perform effectively and are mechanically simple, which reduces the space and maintenance requirements. Primary treatment systems also have a relatively low likelihood of mechanical failure compared to secondary and tertiary treatment systems, making them very reliable. These characteristics make them ideal for NNM platforms. This type of treatment is used at platforms considered analogous to the NNM Crux platform such as Woodside's Angel platform off Australia's Pilbara coast and the Maui-B platform off New Zealand's Taranaki region.

Primary treatment relies on gravity to provide the force that separates the less dense oil droplets from the PFW. Shell expects a primary treatment system on the Crux platform would effectively remove oil droplets down to approximately 30 µm diameter. Primary treatment systems enhance the separation via gravity by facilitating aggregation of oil small oil droplets into larger ones. They are mechanically simple and have high reliability. Shell's preferred primary PFW treatment system is a Produced Water Degasser Vessel.

Primary treatment does not remove dissolved hydrocarbon fractions or dissolved metals, which are typically the most toxic components in PFW.

Primary treatment is considered feasible for the Crux NNM platform and is Shell's preferred PFW treatment option.

**Secondary Treatment**

Secondary treatment removes smaller entrained oil droplets than primary treatment (typically > 10 µm) from the PFW. Secondary treatment may rely on enhanced physical separation via the difference in density between the hydrocarbon droplets and the PFW (e.g. hydrocyclones) or the use of filter material. Secondary treatment can typically remove approximately 90% for oil droplets > 15 µm.

Secondary treatment enhances the physical separation of oil droplets from PFW. Shell expects a secondary treatment system would effectively remove oil droplets down to approximately 10 µm diameter. Hydrocyclones are an example of a secondary treatment system. Hydrocyclones enhance the separation of oil from PFW by spinning the PFW in a circular motion (i.e. hydrocyclones are centrifuges). The less dense oil droplets are forced towards the centre of the hydrocyclone by centripetal force, which enhances the separation of oil droplets from the PFW. Secondary treatment systems are typically mechanically more complex than primary treatment systems, although also have high reliability.

Secondary treatment systems typically require greater maintenance and space compared to primary treatment systems and are costlier to install and operate compared to primary treatment systems. For example, hydrocyclones are mechanically more complex than a Produced Water Degasser, increasing maintenance requirements and the potential for mechanical failures. Filters that use consumable filter elements must be regularly cleaned (e.g. back flushed) or replaced to maintain performance, increasing maintenance requirements. This increases the need to personnel to be onboard the platform.

Secondary treatment does not remove dissolved hydrocarbon fractions or dissolved metals, which are typically the most toxic components in PFW.

Secondary treatment is considered feasible for the Crux platform.

**Tertiary Treatment**

Tertiary treatment systems reduce residual oil droplets in the PFW to very low levels. Unlikely primary and secondary treatment, tertiary treatment may also reduce the concentrations of soluble hydrocarbons and metals in some cases. This results in improved environmental performance as the potential toxicity of the PFW stream is lower compared to other treatment systems.

Tertiary treatment systems that rely on adsorption, such as organoclays or granular activated carbon, become exhausted over time. The adsorption media require regular replacement, which increases the maintenance requirements for the facility. This is not consistent with the Crux platform NNM basis of design. The spent adsorption media waste stream requires storage, handling and disposal, which may lead to potential contaminants being translocated. Changing out of filters also requires personnel to be onboard the platform, which is not consistent with the Crux platform NNM basis of design.

The MPPE tertiary treatment system used on the Prelude FLNG is large in size and requires more space and primary or secondary treatment systems. MPPE also require additional utility systems, such as demineralised water supply, steam generation, cooling water and heat exchangers. Given the space constraints and 'unmanned' operations on the Crux platform, use of MPPE treatment is not feasible.

Based on the discussion above, tertiary treatment of PFW for the Crux project is not considered feasible because:

- tertiary treatment systems, particularly MPPE, will require additional space. These systems may not fit within the space constraints of the Crux NNM platform.
- tertiary treatment systems will require greater maintenance, increasing the frequency and duration of personnel visits to the Crux platform. This increases the safety risks for Shell personnel.

Tertiary treatment of PFW is not feasible for the Crux NNM platform as part of the foundation development and has not been considered further. However, Shell will evaluate the feasibility of, and requirement for, further treatment of PFW throughout the project, particularly once steady state and stable operations are reached and if the additional fields within the in-field development area are developed.

**Buffer Tank**

Buffer tanks provide storage capacity at production facilities. This may be used to temporarily store off specification (e.g. high oil in water concentrations) PFW in the event the treatment system is not meeting specified discharge requirements. Once the performance of the PFW treatment system has improved and meets discharge requirements, the off-specification water in the buffer tank is routed through the treatment system and discharged to sea. This option is commonly used onboard large production facilities with high volumes of available liquid storage, such as floating production storage and offtake (FPSO) platforms. Design studies have shown a storage volume of approximately 100 $m^3$ is the practical limit based on the layout of the Crux NNM platform.

The space constraints of the Crux platform NNM basis of design severely limits the volume of any buffer tank that may be installed on the platform. The capacity of a buffer tank that may be installed on the Crux platform is likely to be exceeded in a relatively short space of time (e.g. in the order of hours to days) if PFW is being directed to the tank. If the off specification PFW is the result of a fault that requires a visit to the platform to rectify, the capacity of the buffer tank is likely to be exceeded before such a visit may be conducted. This would result in off specification PFW being discharged to the sea once the buffer tank is filled.

Installation of a buffer tank onboard the Crux platform is considered feasible, although is unlikely to significantly improve environmental performance.

**Discharge from Platform**

Discharge of treated PFW above sea level from the Crux platform is the simplest method of disposing of PFW to the sea. This approach is commonly used onboard facilities that discharge PFW to the sea. The plunging of the PFW from height into the sea can increase near-field turbulent mixing, which can enhance the dilution of the PFW. This results in more rapid dilution of the PFW in the sea and consequently results in a smaller area that may be impacted by potentially harmful components of the PFW.

Discharging treated PFW directly from the Crux platform above sea level is considered feasible and is Shell's preferred treated PFW discharge option.

**Discharge from Caisson**

Discharge of treated PFW from a caisson below sea level is more complex than discharge above sea level but may have some advantages. Discharge below sea level from a caisson may enhance mixing of relatively buoyant PFW plumes.

In the event of high residual oil levels in the treated PFW (e.g. failure of the treatment system), the caisson will retain some floating hydrocarbons, preventing their discharge to the sea. These hydrocarbons may be recovered by the production facility.

Implementation of a caisson introduces some additional maintenance requirements as it is exposed to waves and seawater. These may be accommodated within the planned and unplanned maintenance allowances for the NNM Crux platform basis of design.

Discharging treated PFW from a caisson at the Crux NNM platform is considered feasible.

### 5.8.2.2 Feasible Option Comparison

Following the feasibility assessment of the identified PFW treatment and disposal alternatives, the following alternatives were identified as being feasibly implemented for the Crux project as part of the foundation development:

- treatment systems:
  - primary treatment of PFW
  - secondary treatment of PFW
- discharge locations:
  - above the sea surface via a pipe, and
  - below the sea surface via a caisson.

The treatment system and discharge location alternatives were compared using the criteria outlined.

**Treatment Systems**

Both primary and secondary PFW treatment systems were considered feasible for the Crux project. Both separate oil droplets from the PFW by physical processes driven by the difference in density between the oil and the PFW. Neither primary or secondary separation remove dissolved materials from the PFW, such as soluble hydrocarbons and metal ions. A comparison of primary and secondary treatment systems using the criteria outlined in **Section 5.8.2** is provided in **Table 5-8**.

Table 5-8: Pairwise Comparison of Primary and Secondary PFW Treatment Systems

| Criterion | Primary Treatment | Secondary Treatment | Conclusion |
|---|---|---|---|
| Environment | Effective removal of oil droplets down to approximately 30 µm diameter results in higher volumes of oil discharged with PFW. Under steady state operations the difference in performance is expected to be negligible.<br>Slightly larger mixing zone for total hydrocarbons compared to secondary treatment. Mixing zone | Effective removal of oil droplets down to approximately 10 µm diameter results in smaller volumes of oil discharged with PFW. Under steady state operations the difference in performance is expected to be negligible.<br>Slightly smaller mixing zone for total hydrocarbons compared to | Secondary treatment is slightly preferred to primary treatment considering the environment criterion. |

| Criterion | Primary Treatment | Secondary Treatment | Conclusion |
|---|---|---|---|
| | for soluble hydrocarbons the same as secondary treatment (i.e. no difference); soluble hydrocarbons are generally the most toxic fraction.<br>No removal of dissolved hydrocarbons or metals. | primary treatment. Mixing zone for soluble hydrocarbons the same as secondary treatment (i.e. no difference); soluble hydrocarbons are generally the most toxic fraction.<br>No removal of dissolved hydrocarbons or metals. | |
| Safety | Mechanical simplicity results in lower maintenance requirements. This reduces the time personnel are required on the Crux platform, reducing their exposure to safety risks.<br>Primary treatment option is slightly preferred to secondary treatment option. | Secondary treatment systems are typically mechanically more complex than primary treatment systems and have greater maintenance requirements. This increases the time personnel are required on the Crux platform, potentially increasing their exposure to safety risks. | Primary treatment is slightly preferred to secondary treatment considering the safety criterion. |
| Technical | Compared to secondary treatment systems, primary treatment systems:<br>• are mechanically simpler<br>• require less space<br>• more reliable<br>• remove less oil, although only marginally less during normal operations. | Compared to primary treatment systems, secondary treatment systems:<br>• are mechanically more complex<br>• require more space<br>• less reliable<br>• remove more oil, although provides little benefit during routine operations due to oil droplet sizes being too small for efficient separation. | Primary treatment is preferred to secondary treatment for the technical criterion. |
| Cost | Primary treatment systems require less space onboard the Crux platform and cost less to procure than secondary treatment systems. These factors reduce the capital expenditure to build the platform or replace the treatment system if required.<br>Maintenance requirements for primary treatment systems are typically lower than secondary treatment systems. This reduces ongoing operational expenditure costs. | Secondary treatment systems require more space onboard the Crux platform and typically cost more to procure than primary treatment systems. Consequently, the capital expenditure to build the Crux platform would be higher if a secondary treatment system is used.<br>Maintenance requirements for primary treatment systems are typically lower than secondary treatment systems. This reduces ongoing operational expenditure costs. | Primary treatment is preferred to secondary treatment for the cost criterion. |

Shell has assessed the potential discharges of oil into the marine environment for early (low PFW discharge rates) and late (peak PFW discharge rates) field life operations for the Crux development using primary and secondary treatment options. Based on the stochastic modelling of PFW discharges (refer to **Section 8.4.8** for further detail), the worst-case dilution of the PFW discharge within 100 m is 1:73. Based on the worst-case residual oil concentrations during late-life operations, the dispersed oil concentration at 100 m from the discharge point would be approximately 0.3 parts per million (ppm) and 0.2 ppm for primary and secondary treatment respectively. These very low concentrations of residual oil (i.e. non-soluble hydrocarbons) have effectively the same potential for environmental impacts. Hence, there is effectively no difference in the environmental outcome at 100 m (i.e. once the discharged PFW plume has been diluted in the environment).

Note that primary and secondary treatment do not remove soluble hydrocarbons from the PFW; there is no difference in the environmental performance or primary and secondary treatment with respect to soluble hydrocarbon fractions.

**Discharge Locations**

Discharge of treated PFW from above the sea (i.e. from a pipe) and below the sea surface (i.e. from a caisson) were identified as feasible options. Based on operational experience, Shell expects the PFW to be slightly warmer and significantly saltier than the receiving tropical seawater. The PFW will be considerably denser than the receiving sea water and the PFW plume will initially be negatively buoyant. As the plume mixes and become more dilute, its density will approach that of the receiving seawater. A comparison of primary and secondary treatment systems using the criteria outlined in **Section 5.8.2** is provided in **Table 5-9**.

Table 5-9: Pairwise Comparison of Above Sea Surface (pipe) and Below Sea Surface (caisson) Discharge of Treated PFW

| Criterion | Above Sea Surface (Pipe) | Below Sea Surface (Caisson) | Conclusion |
|---|---|---|---|
| Environment | Studies based on late-life operations PFW discharge rates indicate that discharge from a pipe has slightly improved mixing compared to discharge from a caisson. This resulted from the fall of the negatively buoyant PFW from the platform plunging into the sea, which enhanced turbulent mixing in the immediate vicinity of the discharge.<br>Discharge from a pipe will not contain any floating oil in the event that PFW treatment system is not functioning effectively (e.g. during mechanical failure). | Studies based on late-life operations PFW discharge rates indicate that discharge from a caisson has slightly worse mixing compared to discharge from a pipe. While the negatively buoyant PFW plume mixes turbulently when discharged from the caisson, it is not expected to mix as effectively as discharge from a pipe above the sea surface.<br>A caisson may retain floating oil in the event that the PFW treatment system is not functioning effectively. However, this is considered to be an unlikely scenario. The capacity of a caisson to retain floating oil is likely to be exceeded before an unplanned maintenance visit to the platform can be scheduled. | Discharge from a pipe is slightly preferred to discharge from a caisson considering the environment criterion due to the enhanced mixing. This outweighs the ability for a caisson to retain floating oil if the treatment system is not functioning effective. |
| Safety | The discharge pipe will require relatively little maintenance, which can be conducted entirely from onboard the Crux platform. | The caisson is likely to require greater maintenance, resulting in increased safety exposure. The caisson may require unplanned maintenance visits. | Discharge from a pipe is preferred to discharge from a caisson considering the safety criteria. |
| Technical | Discharge from a pipe on the platform is mechanically simpler and requires less maintenance. | The caisson would be exposed to the sea and hence would need to be engineered to withstand waves and external corrosion. This makes the caisson more challenging to implement technically. Exposure to waves and corrosion will require greater maintenance during operations than discharge from a pipe on the platform. | Discharge from a pipe is preferred to discharge from a caisson considering the technical criterion. |

| Criterion | Above Sea Surface (Pipe) | Below Sea Surface (Caisson) | Conclusion |
|---|---|---|---|
| Cost | Discharge from a pipe on the platform costs less to fabricate, install and operate than a caisson. | A caisson costs more to fabricate, install and operate than a pipe from the platform. | Discharge from a pipe is preferred to discharge from a caisson considering the cost criterion. |

Discharge of treated PFW above the sea surface from a pipe on the Crux platform is preferred to discharge below the sea surface from a caisson for each of the criteria considered in **Table 5-9**. The only advantage identified by discharging from a caisson is that it would retain floating oil within the caisson in the event that the PFW treatment systems are not functioning effectively.

This advantage is only delivered during a failure of the PFW treatment system which is expected to be an uncommon event. The enhanced mixing of the treated PFW discharge above the sea surface is delivered continuously throughout the production life of the Crux platform. On this basis, discharge from above the sea surface was considered to deliver a better environmental outcome than discharge from the caisson.

If the treated PFW was positively buoyant, discharge from a caisson may result in enhanced mixing compared to discharge above the sea. However, the treated PFW from Crux is likely to be negatively buoyant and discharge above the sea will enhance mixing more than a caisson will.

#### 5.8.2.3 Summary of Selected PFW Treatment Options

The following outlines a summary of the selected PFW treatment technologies during concept select, noting that further evaluation will continue during FEED to further optimise the PFW treatment technologies:

- liquid/liquid separator designed to remove 30 micrometre (µm) oil droplets from water (i.e. primary treatment). Analogue field performance has shown this enables an oil-in-water of acceptable performance under steady-state conditions.
- low-shear, liquid/liquid separator level control valve to maximise size of oil droplets in the produced water streams. Due to pressure drop, oil droplets of approximately 10 µm can be expected downstream of the valve.
- produced water degasser vessel designed to de-gas the produced water and collect any oil droplets separated. This vessel also enables any bulk condensate to be collected in case of upsets in upstream equipment. This vessel may be fitted with internals to promote gas floatation effects.
- space to allow for additional treatment technologies (e.g. secondary treatment such as hydrocyclones) to be installed as part of an adaptive management processes.
- disposal to ocean via piping terminated approximately +8 m above sea level.

### *5.8.3* $CO_2$ Management Alternatives

The project has evaluated a number of significant direct $CO_2$ management alternatives as part of the concept selection. These options included analysis of venting reservoir $CO_2$, implementing carbon capture and storage (CCS) at Prelude or Crux and making allowances in design for future implementation of CCS at Crux. Other direct $CO_2$ management alternatives will continue to be investigated throughout FEED.

Key factors influencing $CO_2$ management alternatives decisions include:

- technical feasibility of GHG mitigation options
- economic impact of the capital and operating costs associated with the various GHG mitigation options

- economic impact of potential future exposure to GHG related costs (e.g. emissions trading scheme, carbon tax) or operational restrictions (e.g. mandatory CCS)
- internal Shell $CO_2$ aspirations and performance standards, and
- impact to proposed NNM operation of the Crux facility, increase in safety risk and to project schedule.

The implementation of other GHG management options require a balance of emissions reduction benefits with the need to be technically and commercially viable.

FEED will be the next stage during which Shell will review practicable options to reduce atmospheric emissions, including alternatives to optimise the selected power generation system.

Implementing CCS

The existing Prelude FLNG facilities contain an AGRU, which is used to remove $CO_2$ from the process gas stream (reservoir $CO_2$) prior to liquefaction. CCS at Prelude would benefit from the use of this existing infrastructure. However, in 2010, as foreseen in the Prelude EIS, the Prelude facility selected venting as the acid gas disposal method, with CCS deselected on economic and technical grounds. Subsequently, the space associated with CCS facilities was reallocated to the MEG system. There is no space available to retrofit $CO_2$ compression onto Prelude FLNG, therefore it is not a technically feasible option.

The option exists to include reservoir $CO_2$ capture and compression on the Crux facility as part of the greenfield scope.

The inclusion of $CO_2$ capture and compression equipment on the Crux platform will significantly increase the operations and maintenance requirements and therefore would likely drive the project towards fully manned operations. Increased offshore manning will have a corresponding increase in worker exposure to process, occupational and structural hazards. The introduction of a high-pressure $CO_2$ process stream will also introduce additional process hazards to the platform. Process requirements are an AGRU for $CO_2$ removal, dehydration and compression.

In addition, the inclusion of the CCS facilities would represent a significant increase in project scope, complexity and associated on and offshore construction and commissioning manpower hazard exposure.

The suitability of the Crux reservoir was also assessed for CCS. On review of the sub-surface feasibility of implementing CCS at Crux, it was concluded that the reservoir was unsuitable as it did not display the characteristics required to effectively contain the re-injected $CO_2$. Therefore, there is potential for $CO_2$ leakage to the seafloor, which has both undesirable environmental and safety implications. The closest suitable location for reservoir $CO_2$ capture is the Montara Formation in the nearby Montara field, which is operated by Jadestone Energy. Access to this field requires substantial commercial negotiations with the Montara venture, which would impact the project schedule and may render the Crux project uneconomic and a no development option would result.

On the basis of economic, operational and safety grounds, the decision has been taken to not deploy CCS as a part of the Crux greenfield development. However, Shell will regularly evaluate GHG mitigation opportunities throughout the project to allow for the consideration of any practicable options, should they become available in the future.

#### 5.8.3.1 Power Generation

The Crux platform will require a source of electrical power to operate the equipment onboard (e.g. process heaters, pumps, lighting etc.). Shell identified several alternatives by which power is supplied to facilities currently used in the offshore oil and gas industry.

The following list of alternatives for the provision of power to the Crux platform were identified:

- powered remotely from Prelude FLNG by an umbilical
- powered by gas engines onboard Crux platform
- powered by gas turbine generators onboard Crux platform
- powered by photovoltaic (solar) onboard Crux platform, and
- power supply augmentation from battery energy storage system.

Each option was assessed to determine if it would be feasible for the Crux project.

### 5.8.3.2 Option Feasibility Assessment

**Remote Power from Prelude FLNG**

The option of powering the Crux platform via an umbilical from the Prelude FLNG running along the export pipeline was considered. The Prelude FLNG facility was not designed to generate nor export power for additional facilities and does not currently have excess power generating and transmission capacity to do so. Installing additional power generation and transmission facilities onboard Prelude FLNG is not possible due to the space limitations aboard the facility. On this basis, powering the Crux NNM platform from Prelude FLNG is not feasible.

**Gas Powered Reciprocating Engines Onboard Crux Platform**

Gas-powered reciprocating engines using gas produced by the Crux platform may be used to provide electrical power. The efficiency of the gas engines is not expected to be better than the gas turbines as although they have the potential to burn more efficiently at low load (compared to gas turbines) the Crux facility will operate at high loads over the life of the Asset. It is expected that gas engines utilised for Crux would have lower reliability and higher maintenance requirements than gas turbines, which does not align with the Crux NNM requirements. For this reason, they have not been selected for Crux.

**Gas Turbine Generators Onboard the Crux Platform**

Gas turbine generators are commonly used onboard offshore oil and gas facilities. Gas turbines are compact, have high reliability, require relatively little maintenance and can be run using fuel gas produced by the Crux platform. These characteristics often make this technology preferable for generating electrical power offshore. Gas turbines are considered feasible for use on the Crux NNM platform.

**Photovoltaic Generation Onboard the Crux Platform**

Photovoltaic generation on the Crux NNM platform was assessed however the space required for these panels would be an order of magnitude larger than that available on the platform and as such is not a feasible option.

Although photovoltaic power is not feasible for the main power supply on the Crux platform it may be considered as a supplementary power source during the FEED process.

**Battery Energy Storage Onboard the Crux Platform**

A battery energy storage system has been considered in conjunction with the main power generation system to better stabilise power loads and potentially increase efficiency of the system. Initial studies show limited benefits of utilising a battery system and the feasibility of such a system on a NNM facility has not been confirmed. The base case for

Crux does not rely on a battery storage system, however the integration of battery system either for the main power supply or supplementary power will be considered in FEED.

#### 5.8.3.3 Feasible Option Comparison

Of the power generation options identified by Shell for the Crux platform, gas turbine generators were identified as having the greatest overall benefits for Crux and provided suitable high efficiency options. Gas turbines are commonly used for power generation at offshore facilities and are suitable for use on unmanned platforms.

Shell continuously appraises the development of power generation technology, and options that are not feasible at this time may become so in future.

The FEED process for the Crux platform will consider the application of alternative energy systems for supplementary power loads on the Crux project and potential integration of battery systems.

### 5.8.4 Do Nothing Alternative

The project aligns with the Australian Government's broad mandate to develop offshore oil and gas resources. Specifically, the policy of the Australian Government in relation to the development of offshore oil and gas resources is to increase investment in petroleum development in offshore areas under Commonwealth jurisdiction. The Government recognises that investment in this area provides benefits to the Australian community through the following:

- taxation revenues
- employment
- regional development
- provision of back-fill gas for the continued operation of existing infrastructure such as the Prelude FLNG facility, and
- enhanced energy security.

In addition, to satisfy offshore permit retention lease requirements, Shell and its JV partners have an obligation to undertake exploration and develop any commercially viable hydrocarbon reserves. In this context, the 'no development' alternative is not consistent with the legal obligations and commercial objectives of Shell and was not considered further.

Shell is committed to supporting the energy transition in a responsible and sustainable manner. It is recognised that achieving net-zero emissions essentially involves re-wiring of the whole global economy, while at the same time meeting greater energy demand due to population growth, development, new energy services, and the extended use of existing services. There is yet no clear development pathway for an emerging economy that does not include traditional energy sources and the drive towards net-emissions is challenging due to the current lack of low-carbon substitutes for many emission intensive industries. Gas is recognised as an important fuel in the energy transition, especially for economies which are currently powered by coal and is key to reducing GHG intensity of the energy supply chain. The Crux project, therefore, contributes to this transition.

## 5.9 HSE Design Standards

The HSE requirements of the project start with compliance with the Australian Commonwealth and applicable state and territory legislation, and applicable internationally HSE codes, standards and guidelines, as specified in **Section 2** of this OPP. In addition, international agreements to which Australia is a party have been applied, as well as Shell Group Policies, Standards, Procedures and Guidelines including:

- Shell Design and Engineering Practices, and

- Shell HSSE & SP Control Framework.

The design mitigations, together with the management measures that will be developed, will ensure risks are acceptable at this stage of project evaluation.

# 6 Description of the Existing Environment

## 6.1 Introduction

This section describes the key physical, biological, socio-economic and cultural characteristics of the existing environment that may be affected by the project, both from planned activities and emergency events. The description of the environment is comprehensive and describes the environmental values and sensitivities, including MNES as defined under the Commonwealth EPBC Act, within two areas:

- the project area, which consists of the in-field development area and export pipeline corridor (as defined in **Section 5.3.1**), and
- the potential area of influence associated with the project (as defined in **Section 6.1.1**). The potential area of influence will be further refined as future detailed engineering information becomes available and will be presented in the activity-specific EPs.

The description provided in this section has informed a detailed evaluation of all impacts and risks associated with the project for the project, as presented in **Section 8**.

### 6.1.1 Project Area of Influence

As outlined above, this OPP considers the potential impacts and risks to the existing environment that may be affected from both planned activities within the project area (**Figure 5-3** and **Figure 5-4**) and emergency events.

The extent of the environment that may be affected from liquid discharges associated with the project was informed by discharge modelling studies, as discussed in **Section 8.4.8**.

The ‘area of influence’ defines the outer boundary of the existing environment that may be affected from emergency events, as shown in **Figure 6-1**. The area of influence was derived using the maximum spatial extent of the low exposure zone from the stochastic modelling studies of the worst-case credible hydrocarbon spill scenarios identified for the Crux project (**Section 8.4.9**). As such, the area of influence was created by merging all of the modelling results, although it is characterised by the entrained hydrocarbon fraction of loss of well control scenario. This scenario has the longest duration and releases the greatest volume of hydrocarbons of all the credible worst-case scenarios that may occur during the Crux project. The area of influence includes all areas where hydrocarbon levels exceed threshold concentrations. This approach has facilitated the assessment of all environmental values and sensitivities that could potentially be affected by the project and has formed the basis of the EPBC Protected Matters search. Refer to **Section 8.4.9** for further information on the worst-case credible hydrocarbon spills and associated modelling studies.

A low exposure threshold, which represents a visible oil (rainbow) sheen, has been used to provide an indication of the extent to which stakeholders may visually observe oil on the sea surface. This is considered to provide a conservative extent of potential impacts to socio-economic receptors associated with visual amenity. The description of the socio-economic environment in **Section 6.6** covers this wider area of influence.

It is important to note that biological impacts are not expected to occur within the entire area of influence. Refer to **Section 8.4.9** for discussion of the biological impact thresholds (i.e. moderate thresholds).

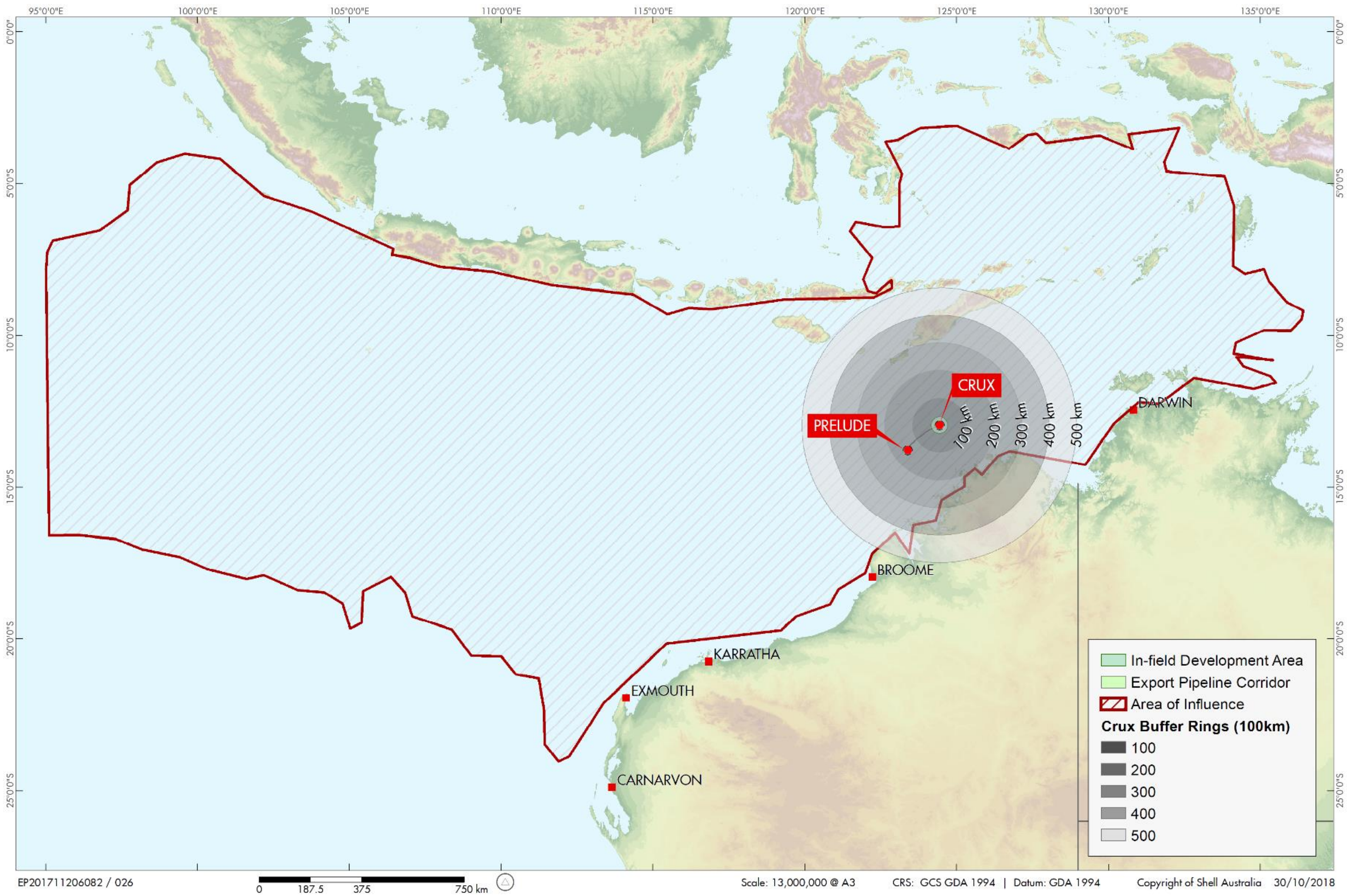



Figure 6-1: Area of Influence for the Crux Project
Note the western margin of the Area of influence is the edge of the model domain of the hydrocarbon spill modelling studies.

## 6.2 Data Sources

### 6.2.1 Desktop Study

A wide range of scientific literature were used to inform the detailed assessment of environmental values and sensitivities in this OPP. The key sources of information included:

- baseline marine studies program undertaken by Shell to inform the existing context of the in-field development area and pipeline corridor – these are summarised further in the following **Section 6.2.2**
- the Applied Research Program (ARP) undertaken by the Australian Institute of Marine Science (AIMS) and associated industry partners
- material published by the DoEE, including EPBC Protected Matters search tool, species profile and threats database, National Conservation Values Atlas, biologically important areas (BIAs) and internesting habitat critical to the survival of marine turtles, recovery/management plans and conservation advices, bioregional marine region plans, conservation value report cards, threat abatement plans, National strategies and Australian marine park management plans
- State and Territory Government publications, including material published by DBCA, Department of Planning, Lands and Heritage (DPLH) and DPIRD, such as marine park management plans, heritage databases and fisheries status reports
- recent Environment Plans of relevance to the Crux project and surrounds, including the AC/RL9 EP for the Auriga West-1 exploration drilling (Shell 2014), and the Prelude EPs for subsea installation (accepted 2014), operations (accepted 2016) and wellhead removal (accepted 2017)
- published EIS/offshore referral study reports to inform the regional environmental context, including:
    - Shell Prelude FLNG EIS (Shell 2009), and Supplement (Shell 2010), EPBC 2008/4146. As part of the Prelude EIS, a range of technical studies were undertaken to inform the existing environment and have been referenced where relevant in this OPP
    - Woodside. 2011. Browse LNG Development, Draft Upstream EIS EPBC Referral 2008/4111 (November 2011)
    - Woodside. 2013. Floating LNG EPBC referral 2013/7079 (December 2013), Draft EIS (November 2014) and EIS Supplement (May 2015)
    - INPEX. 2010. Ichthys Gas Field Development Project Draft EIS, and subsequent EIS Supplement (April 2011), and
- published literature on the regional environmental values and sensitivities, e.g. PTTEP surveys initiated in response to the Montara incident (Heyward et al. 2010; Heyward et al. 2012) and as published on the North West Atlas.

### 6.2.2 Crux Project Studies

Shell has commissioned a number of baseline studies to characterise the existing marine environment relevant to the project. These baseline studies built on the knowledge undertaken through the ARP in collaboration with AIMS and industry partner INPEX. A summary of the baseline studies is provided in **Table 6-1**. The locations of key baseline monitoring locations are shown in **Figure 6-2**.

The modelling studies undertaken to inform this OPP are also outlined in **Table 6-1**.

Table 6-1: Summary of Crux Baseline Studies

| Study Type | Study Description/Objective | Reference |
|---|---|---|
| *Field Studies* | | |
| Metocean study | Collection of metocean data (e.g. current, conductivity, wave and wind data) on the surface and through the water column for a full 12-month period from late April 2016 to early May 2017 within and in the vicinity of the Crux field and along the planned pipeline route to Prelude. | RPS Metocean (RPS) 2017 |
| Water quality study | Collection of baseline data on physical and chemical components of water quality, along the proposed pipeline corridor and within the Crux field. The surveys were completed over two survey events in April/May 2016 and October/November 2016. | AECOM 2016 (**Appendix A**) |
| Sediment, water quality and infauna study | Collection of baseline data on sediment quality, water quality and infauna communities, along the proposed pipeline corridor and within the Crux field. The study was completed in October/November 2016. | AECOM 2017 (**Appendix B**) |
| Benthic habitat study | Collection of baseline data to characterise topographic features, benthic habitats and macrofaunal communities, along the proposed pipeline corridor and within the Crux field, through the use of underwater transects (towed video camera) and geophysical methods (multibeam, side-scan sonar, seismic reflection and sub-bottom profiling). This study was completed in April/May 2017, as part of a combined geophysical and environmental survey scope.<br>The survey considered an alternative pipeline corridor near the Prelude FLNG facility end, as shown in **Figure 6-2**, to account for a previously identified seabed ridge traversing the south-western end of the proposed pipeline area. The area in the vicinity, which encompassed part of this ridge, were also surveyed. While this alternative route is no longer being carried forward into the OPP it has been presented for completeness. | Fugro 2017a (**Appendix C**) |
| AIMS Applied Research Program (ARP) | Shell is an industry partner, together with INPEX, in support of the AIMS ARP, to develop a comprehensive environmental baseline for waters in the Browse Basin.<br>As part of this project, AIMS is leading a collaborative partnership of trusted research organisations including CSIRO, the University of WA, Curtin University, Monash University and the Western Australian ChemCentre.<br>The ARP research programs of particular relevance to informing the regional baseline context are:<br>ARP 2 – Baseline hydrocarbon surveying in the Browse Basin<br>ARP 4 – Evaluating the effects of hydrocarbon exposure on non-avian marine wildlife<br>ARP 6 – Investigating the breeding and foraging parameters of seabird species in the Browse Basin to determine their vulnerability to impacts associated with potential oil spills, and their ability to recover<br>ARP 7 – Subtidal benthos: towards benthic baselines in the Browse Basin.<br>ARP 2 and ARP 7 are of particular relevance to this OPP. The other ARPs are of more relevance to informing the subsequent activity-specific EPs. | ARP 2: CSIRO 2017<br>ARP 7: Heyward et al. 2017a |
| Geotechnical study | An assessment of the geotechnical conditions of the seabed in the Crux field and along the proposed pipeline. This study was completed in 2016, with a further study completed in April 2018. | Fugro 2017b |
| *Modelling Studies* | | |

| Study Type | Study Description/Objective | Reference |
|---|---|---|
| Drill cuttings and drilling muds dispersion modelling study | To calculate the fate of discharged drill cuttings and unrecoverable drilling muds, including the likely area of coverage, bottom deposition (thickness and accumulated load) and assess the risk to key values and sensitivities from contact with cuttings and muds discharged during development drilling operations. | RPS 2018a (**Appendix D**) |
| PFW modelling study | To quantify the extent of the mixing zones of the PFW discharge (based on the maximum pre and post PFW breakthrough flow rates) and assess the potential risk to key values and sensitivities under various seasonal conditions. | RPS 2018b (**Appendix E**) |
| Pipeline hydrotest discharge modelling study | To quantify the potential mixing zone from the release of chemicals within the hydrotest discharge (e.g. biocides) during commissioning activities. | RPS 2018c (**Appendix F**) |
| Hydrocarbon spill modelling study | To quantify the movement and fate of spilled hydrocarbons that would result from an accidental, uncontrolled release from four determined scenarios that are considered representative of the maximum credible worst-case spills that could result from project activities. The scenarios include a well blowout during development drilling, a significant rupture of the export pipeline during operations, a spill from the Crux platform and a pipelay vessel collision during installation of the export pipeline.<br>The study assessed the potential risk to key values and sensitivities from these spill scenarios. | RPS 2018d (**Appendix G**) |
| Hydrodynamic model validation study | Data from the metocean study were used to validate the underlying hydrodynamic model used to develop the liquid discharge and oil spill models. The results of the study have been incorporated into RPS 2018a-d. | RPS 2018e |
| Light modelling study | To characterise the sources of light emissions from the operation of the Crux project and assess the predicted impact of light in the context of the nearest sensitive receptors. | Imbricata 2018 (**Appendix H**) |
| Underwater noise modelling study | To predict the effects of underwater noise emissions from the Crux project, specifically piling of the Crux platform footings and from vessel movements during operations, on key values and sensitivities. | SVT 2018 (**Appendix I**) |

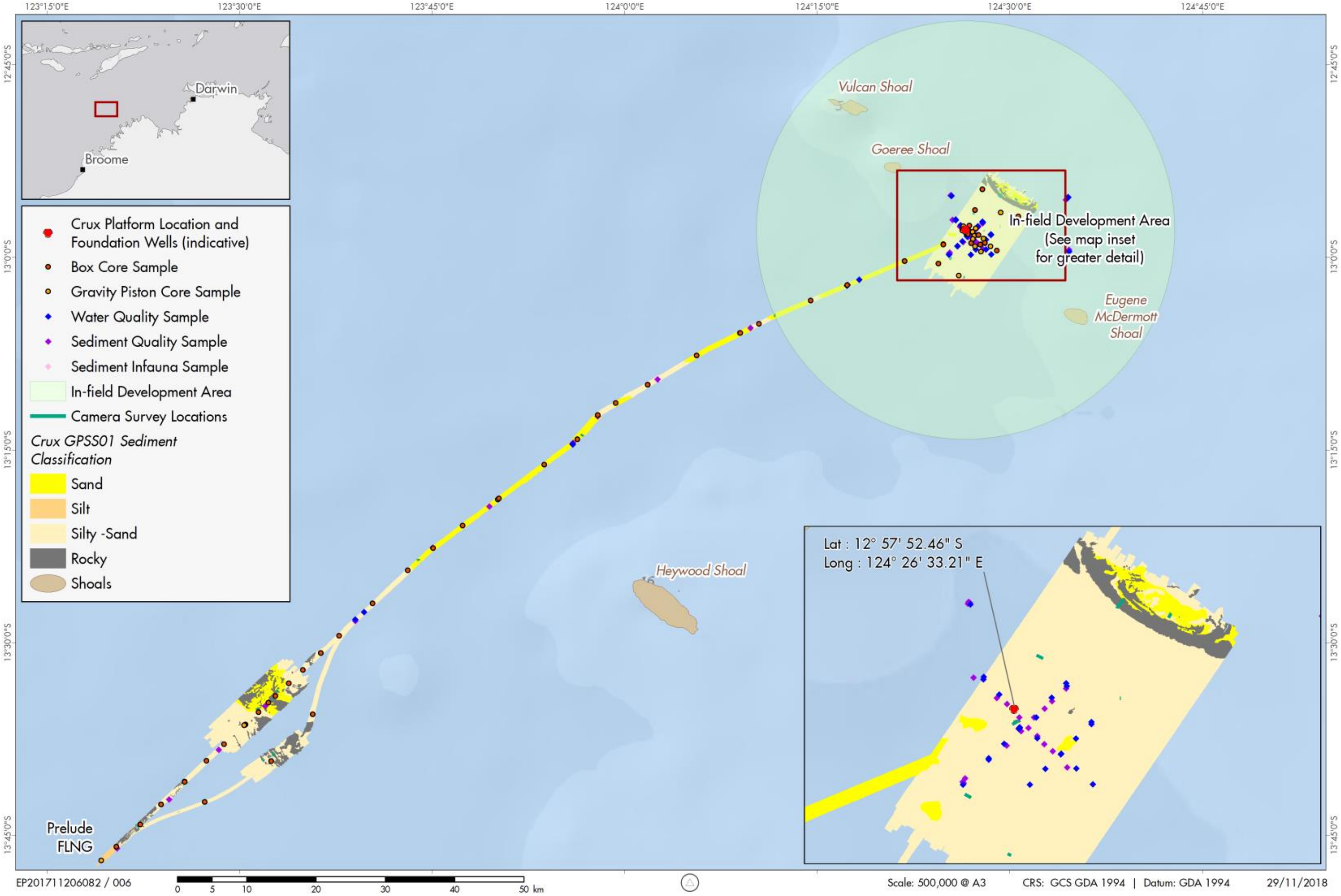



Figure 6-2: Crux Environmental Baseline Monitoring Locations

## 6.3 Physical Environment

### 6.3.1 Climate

The Browse Basin and Timor Sea region experience a tropical climate with two distinct monsoonal seasons, a winter or “dry” season from April to September and a summer or “wet” season from October to March (RPS 2017). This is a result of the two major atmospheric pressure systems of the region; a subtropical ridge of high pressure cells (highs or anticyclones) and a broad tropical low pressure region (the monsoon trough or inter-tropical convergence zone) (RPS 2017). The southeast trade winds originating over the mainland provide a steady easterly air flow to the region in the dry season. The monsoon trough is characterised by the reversal of these winds and brings high rainfall when it is in close proximity to, or over the mainland (RPS 2017).

Meteorological data collected from the Bureau of Meteorology (BoM) weather station located at Cygnet Bay, selected as a station closest to the project area with long term climatic data. While it is recognised this station is in a coastal location, the data is expected to be broadly representative of the region. Average air temperatures vary from 25.8 °C to 36.6 °C in the winter months, and 30.3 °C to 36.7 °C in summer (BoM 2018a). Average seasonal rainfall for the region ranges from 117 mm per month in summer to 19.5 mm per month in winter (BoM 2018b). Observations from the RPS (2017) metocean study, which comprised collection of 12 months of data in the offshore project area, noted that air temperatures remained relatively stable, with mean monthly temperatures ranging between 27 °C in August and 30 °C in December (RPS 2017).

### 6.3.2 Oceanography

The oceanography of the project area and the wider region is influenced by the large-scale ocean currents, monsoonal seasonality in wind and wave action, as well as storm and tropical cyclone events. A summary of these influencing factors is provided in the following sections.

As outlined in **Section 6.2.2**, a baseline metocean study conducted by RPS was undertaken from April 2016 to May 2017 in order to characterise the local current behaviour at the in-field development area and along the export pipeline corridor (RPS 2017). The study also captured meteorological and surface wave measurements within the project area. The key results from this study are discussed in the sections below.

#### 6.3.2.1 Tides and Current

**Regional**

The project is located within the North West Marine Region (NWMR) which experiences semi-diurnal tides. Tidal ranges of between 3 m (neaps) and 10 m (springs) (Brewer et al. 2007), and 2 m (neaps) and 12 m (springs) (Ivey et al. 2016), for example, have been recorded as representative of the Kimberley region. These tides have been shown to strongly influence regional currents in the NWS due to their large tidal range (Brewer et al. 2007; Ivey et al. 2016; RPS 2017). Notably, tidal amplitudes seem to be retained at large distances offshore and travel initially in a north-east direction in the deeper waters of the region (RPS 2017).

A strong seasonal wind regime is closely associated with seasonality in surface currents in the region. **Figure 6-3** indicates the key regional currents influencing the NWMR and wider region (DEWHA 2008a). The Holloway current is the prevailing seasonal current, travelling south-west along the north West Australian coast in winter and north-east in summer (Brewer et al. 2007). The Indonesian Throughflow (ITF) and Holloway surface currents are the predominant currents affecting the North West Shelf (NWS) from February through to June. During this period the ITF produces flows of warm, low-salinity water onto the NWS (Shell 2014). The reversal of these currents caused by strong south-westerly winds at other times of the year may cause anti-clockwise circulation and a northward movement of water and upwellings of cold water onto the NWS (DEWHA 2008a).

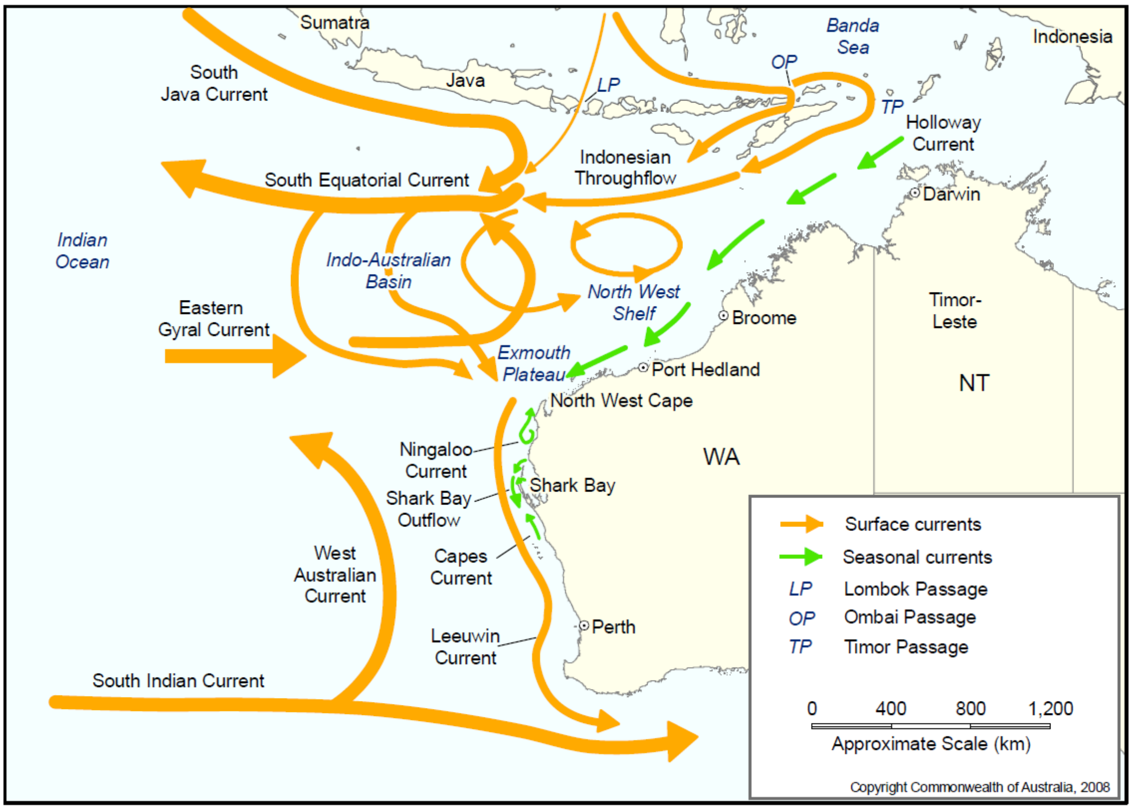



Figure 6-3: Key Regional Currents Influencing the Waters of North-west Australia

**Crux Project Area**

Currents within the project area are broadly typical of the region and predominantly affected by seasonality and driven by tidal variation. The RPS (2017) metocean study reported a mean tidal range between approximately 0.8 m (neaps) and 5 m (spring) within the project area. Prevailing tides in the project area generally flow along a north-west to south-east axis (RPS 2017). Barotropic tides are expected to be less powerful in the deeper waters of the project area and during neaps due to less tidally-induced friction (RPS 2017). Currents within the project area are also influenced by interactions with site-specific seafloor topography and water column stratification (RPS 2017). The occurrence of internal current-driven waves is dependent on variations in localised seafloor topography, such as a continental slopes or shelf breaks, interacting with water moving through the thermocline (DEWHA 2008a). Given the stratification, water depth and regional bathymetry at the in-field development area, it is a site of significant internal wave activity. Based on the metocean study, internal wave action at the in-field development area was typically in the form of well-developed soliton wave packets, whereas areas of the export pipeline corridor were influenced by large waves during spring tides and localised bathymetry (RPS 2017). High frequency currents generated by internal wave action were observed to be strongest in the project area toward the end of winter as this was when the upper mixed layer was at its deepest (RPS 2017).

#### 6.3.2.2 Waves

**Regional**

Regional wave action consists of sea-waves, which are shorter period waves generated at a local level in response to wind conditions, and swell-waves, which result from larger scale ocean storm weather originating from the Southern Ocean or southern portion of the Indian Ocean. Wave action generated during tropical cyclones may be affected at distances of up to several hundred kilometres (RPS 2017).

**Crux Project Area**

Wave conditions in the project area are relatively consistent throughout the year with variations predominantly influenced by monsoonal seasonality in wind patterns and tropical cyclone events (Shell 2014). Persistent levels of swell originating from the Southern Ocean, moving in a west-south-west to westerly direction, are amplified by locally generated swell in summer. Conversely, easterly Trade Winds contribute an additional east-north-easterly swell to the local area in winter (RPS 2017). The summer months are associated with seas and swells from a west-north-west direction (RPS 2017).

#### 6.3.2.3 Water Temperature

**Regional**

The ITF influences the sub-tropical water temperatures of the NWMR and the depth of the permanent regional thermocline (Brewer et al. 2007). Internal tides may also influence this thermocline and cause rapid changes in temperature at depths of 50 m–150 m. Mean regional sea-surface temperatures have been recorded at 28.5 °C with limited seasonal variation (Brewer et al. 2007).

**Crux Project Area**

The metocean study observed average surface water (<10 m) temperatures to be generally consistent within the project area, ranging from approximately 27 °C to 32 °C over a 12-month period (RPS 2017). Surface water temperatures were highest in November and December due to the calm conditions of the extended transition period between winter and summer (RPS 2017). Temperatures near the seabed and up to approximately 60 m above the seabed (ASB) clearly reflect the spring-neap tidal variation, whilst mid-waters of approximately 20 m–70 m ASB were stable (RPS 2017). The thermocline was typically located around mid-water depth (RPS 2017). Cyclonic events and storm activities were observed to result in increased mixing of the water column to depths of up to approximately 80 m before re-stratification occurred (RPS 2017).

#### 6.3.2.4 Severe Weather Events

**Tropical Cyclones**

The NWMR is an area of high cyclone activity (Brewer et al. 2007). Tropical cyclones typically form in the Timor and Arafura Sea areas during an active monsoonal trough and are associated with torrential downpours and potentially destructive winds. While tropical cyclones commonly form during the summer season (October to March), they may also occur within transitional seasons. The average tropical cyclone frequency for the Timor and Arafura Seas region is one cyclone per year with cyclones most commonly occurring between November and April (BoM 2018c).

Tropical cyclone intensity and frequency in northern Australia is also influenced by the El Niño-Southern Oscillation (ENSO), a natural climate cycle that influences the year to year variability of the Australian climate (BoM 2018d). The two phases of ENSO are termed El Niño and La Niña. La Niña occurs when the equatorial trade winds become stronger, bringing warmer surface waters to the western Pacific and northern Australia (BoM 2018d). This is associated with an increase in rainfall and risk of flooding in northern and eastern Australia, as well as an earlier monsoon onset and above average rainfall during the early summer months (BoM 2018d). The La Niña phase creates favourable conditions for tropical cyclone development to the North of Australia and, on average, twice as many tropical cyclones make landfall during La Niña phase (BoM 2018d).

**Squalls**

Associated with thunderstorms in the Timor Sea, squalls occur during summer and are caused by strong downdraft winds. Whilst typically short in duration (i.e. a matter of hours as opposed to days), squalls can often be accompanied by heavy rain and can produce strong currents and increased localised wave activity (RPS 2017).

**Tsunamis**

The project area is relatively exposed to tsunamis originating from the Sunda Arc, which is approximately 250 km north-of the Crux platform, where the Australian Plate is subducting beneath the Sunda Plate (Burbidge and Cummins 2007). However, the tsunami potential for the NWS and Browse Basin is considered moderate and tsunamis at water depths such as those within the project, pose few concerns as they remain relatively small (Geoscience Australia 2018).

### 6.3.3 Bathymetry and Seabed Features

A survey to characterise the benthic habitat at the project area was carried out in 2017 by Fugro and included mapping the bathymetry and seabed characteristics of the in-field development area and export pipeline corridor (Fugro 2017a).

Water depths at the in-field development area range between approximately 90 m and 180 m. The seabed is generally relatively flat with a gentle gradient falling from the north-east toward the deeper south-west corner. Along the export pipeline, the general bathymetric profile is characterised by an overall increase in depth in a south-westerly direction, reaching a maximum depth of approximately 280 m.

Seabed morphology across the project area is typically smooth and bare of hard substrates, with predominantly sandy sediments observed (Fugro 2017a). Muddy sand was more common at the Prelude end of the export pipeline corridor and gravelly sand with hard substrate identified in the shallower north-eastern zone of the in-field development area. Seabed features observed throughout the project area included clusters of pockmarks, sand waves, megaripples and some anchor drag scars (Fugro 2017a).

A large outcropping reef area was identified by the Fugro (2017) survey in the north-eastern section of the in-field development area and extended up to approximately 40 m above the seabed (**Figure 6-4**; Fugro 2017a). The feature is characterised by a steep southern wall and irregular morphology due to smaller reef developments around the flanks and on the plateau, and clusters of seabed depressions on the top of the outcropping area where a layer of loose sediment has accumulated. The seabed along the southern edge of the reefal outcrop was observed to generally rise 10 m – 20 m over a distance of 30 m along the steepest sections. It is thought that this reef structure is similar in origin to the many other shoals in the wider region (Fugro 2017a). The seabed around the feature comprises of a mixture of silt and sand. The seabed on the plateau is characterised by the same seabed composition as the surrounding area with areas of consolidated rock outcrops. A study of the seafloor undertaken in the Browse Basin observed that small, but prominent, mounds were scattered throughout the study area. The mounds were similar to that recorded in the in-field development area in that they were generally steep-sided, rose to similar heights above the seabed (approximately 6 m – 16 m) and comprised of hard substrate (Howard et al. 2016). The mounds also extended up to diameters of more than 30 m. Review of bathymetry at a regional level has identified that the outcropping reef feature forms part of an extensive seabed ridge that occurs at an average depth of approximately 100 m. The broader extent of the ridge, as indicated by the seabed bathymetry, is shown in **Figure 6-5**.

A trench, whereby the seabed drops by up to 25 m over a distance of 50 m, and a platform of 20 m–30 m elevation in relation to the surrounding seabed, were observed within the wider area surveyed along the export pipeline corridor. While in the vicinity of the export pipeline corridor, the export pipeline will not intersect these features.

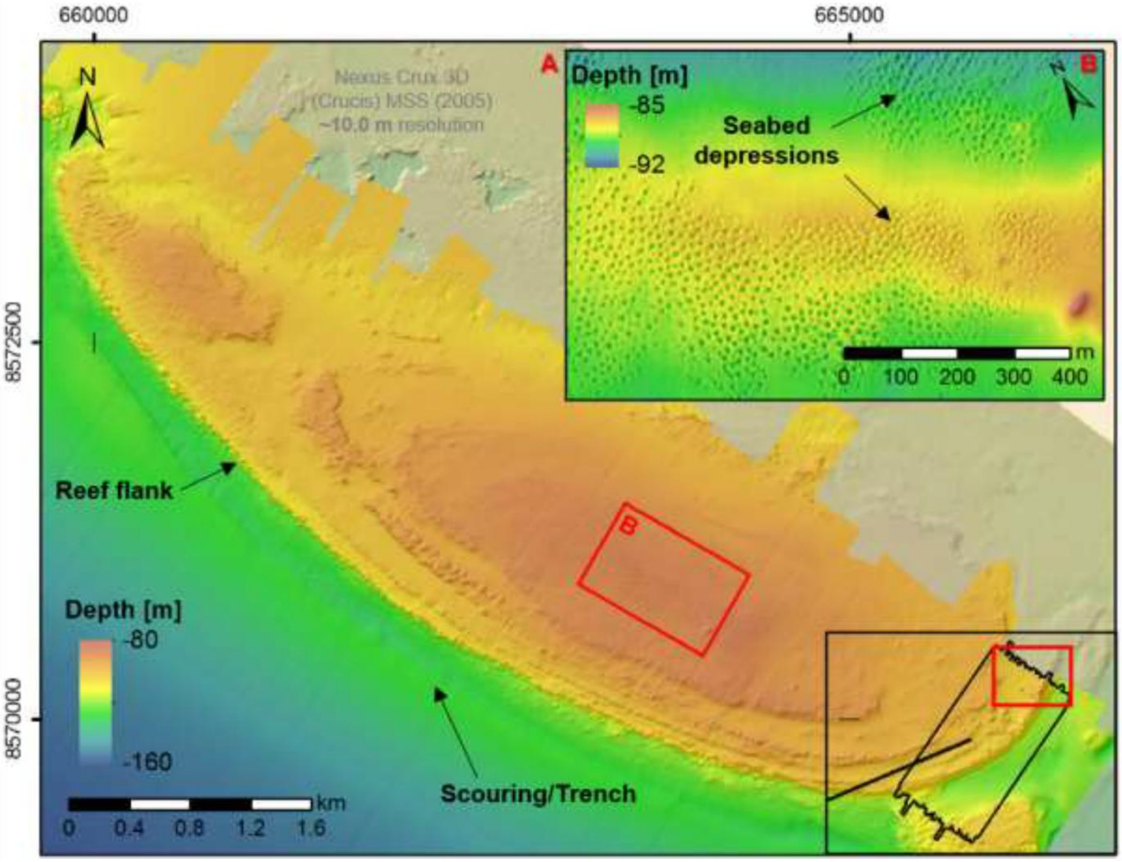



Figure 6-4: Outcropping Reef in the In-field Development Area

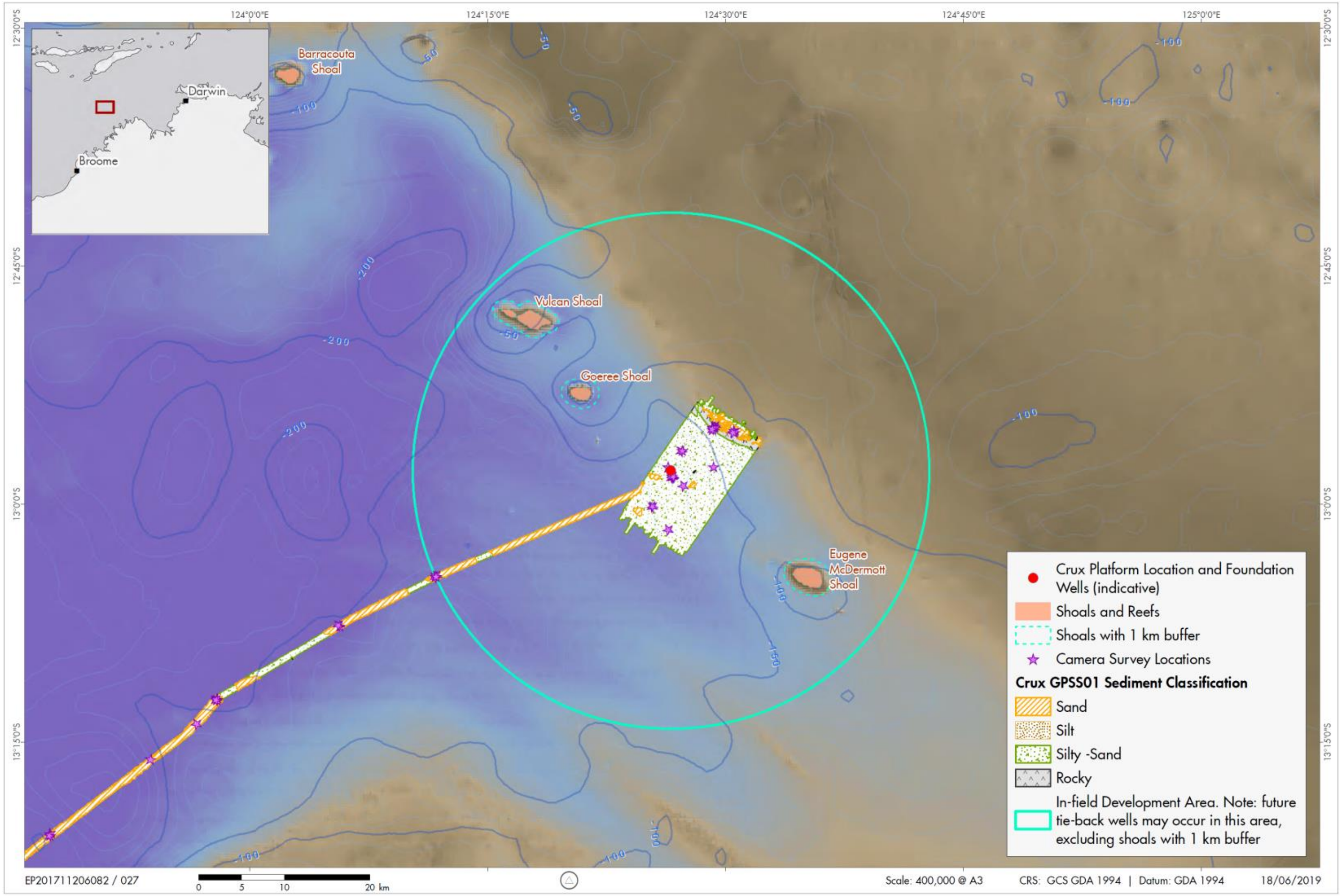



Figure 6-5: Outcropping Reef and Regional Seabed Ridge Feature

### 6.3.4 Water Quality

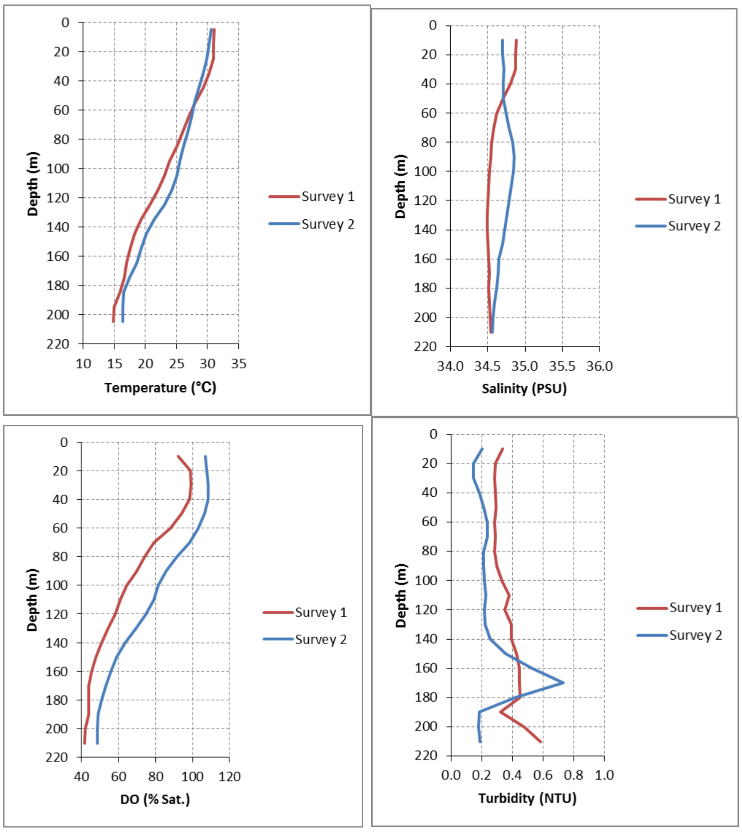
This section describes the water quality recorded within the project area during baseline environmental surveys. Two separate surveys were conducted over three days in April/May 2016 (the ‘May survey’) and October/November 2016 (the ‘November survey’) to reflect seasonality (AECOM 2016, 2017). In the May survey, a total of 24 sites were sampled, 21 sites were within the in-field development area and three were within the export pipeline corridor. In the November survey, ten of these sites were re-sampled, seven in the in-field development area and three within the export pipeline corridor. Vertical profiling, water sampling for nutrient and chemical analysis, and phytoplankton sampling were carried out at sample sites in both surveys.

Where appropriate, water quality data have been compared to the Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand (ANZECC & ARMCANZ) (2000) guidelines. Notably, the guidelines are intended to be modified to capture variabilities at regional, local and/or site-specific levels.

Overall, water quality in the project area was considered to be of high quality.

#### 6.3.4.1 Physico-chemical Water Column Profiles

Temperature, salinity, pH and dissolved oxygen (DO) were relatively consistent across all sites and well within expected ranges when compared to previous studies in the region, such as Prelude (Shell 2009), Ichthys (INPEX 2010) and Barossa (ConocoPhillips 2018). Between the May and November surveys there were marginal consistent differences in DO and pH throughout the water column, as well as comparatively lower salinities in the upper water column for the November survey followed by a gradual increase then decrease in salinities on approaching the seabed (**Figure 6-6**). These physico-chemical variations in water quality between the two surveys suggest the existence of minor seasonal variation.




Key: Survey 1 – May survey; Survey 2 – November Survey

Figure 6-6: Water Column Profiles at Comparable Sites in the In-field Development Area

Surface temperatures (in the shallow profile up to 10 m depth) ranged between approximately 30 °C to 31 °C for both surveys (AECOM 2016, 2017). Temperatures dropped consistently throughout the water column with the thermocline being relatively indistinct (**Figure 6-6**). Temperatures near the seabed typically ranged between approximately 17 °C to 20 °C, however temperatures around 15 °C were recorded at the deeper depths within the export pipeline corridor.

Average surface salinities (0 m–10 m) were recorded between 34–35 Practical Salinity Unit (PSU). While there was some variation in the salinity profile within the water column (**Figure 6-6**) salinities were generally slightly lower near the seabed when compared to the surface waters.

Surface water pH was found to range between approximately 7.9 and 8.3 and pH was consistently higher in the November survey, excepting one site within the in-field development area where the pH was slightly lower (approximately 0.2). Average pH was generally uniform to approximately 20 m–30 m depth. There was then generally a constant decrease through the water column to the seabed where pH values were observed to be slightly lower within the same survey at most sites. However, at some sites a slight increase in pH between 40 m and 60 m depth in the water column was observed. These readings are consistent with expectations for offshore marine environments as outlined in ANZECC & ARMCANZ (2000).

Average DO percent saturation was higher in the upper water column and decreased consistently with depth to the seabed. Average surface DO percent saturation ranged from approximately 86–109%, with DO near the seabed ranging between approximately 41% to 56%. The high levels of DO in surface waters is consistent with mixing in the upper water column.

Turbidity was consistently low throughout the water column (< 1 NTU) for both surveys, which can be expected for offshore marine environments.

#### 6.3.4.2 Hydrocarbons and Metals

Water sample analyses found concentrations of total recoverable hydrocarbons (TRH) and benzene, toluene, ethylbenzene and xylene (BTEX) were not detectable above the Practical Quantification Limits (PQLs) or ANZECC & ARMCANZ (2000) guideline trigger values. The data indicates there was no detectable anthropogenic or natural contamination from neighbouring regional petroleum activities or natural seeps at the time of this study. Due to the open ocean context of the project, the occurrence of natural hydrocarbon seeps in the area (see **Section 6.3.4.4**) and the numerous petroleum activities in the NWS, it should be considered that temporal variation in background TRH and BTEX levels may occur within the project area.

Sample analyses for total metals typically returned concentrations below the PQLs. Exceptions to this were generally well below ANZECC & ARMCANZ (2000) guideline trigger values (99% species protection trigger values for marine waters) and/or within expected levels for offshore marine environments. An exception of note was zinc which was detected above the PQL (0.005 mg/L) and ANZECC & ARMCANZ (2000) guideline 99% species protection trigger value (0.007 mg/L) at one site within the in-field development area (0.021 mg/L) in the May survey only. The November survey subsequently detected zinc above the PQL and ANZECC & ARMCANZ (2000) guideline trigger values at all sites, with concentrations ranging from 0.01 mg/L–0.046 mg/L. The consistently elevated concentrations of zinc recorded suggest potential contamination from laboratory processes and/or sample contamination during collection. In light of this, measurements of zinc at sites in the November survey cannot be regarded as representative for the project area and should not be used in defining baseline trigger values for zinc in the area.

#### 6.3.4.3 Nutrients and Photosynthetic Pigments

Nutrient concentrations, including nitrite and nitrate, total nitrogen and total phosphorus, were consistently low across sites for both surveys, as were levels of photosynthetic pigments indicating little seasonal variation in these properties and no obvious nutrient loads.

PQLs were exceeded for nitrite and nitrate concentrations at four sites (0.01 mg/L–0.05 mg/L) in the May survey. The PQL was lowered to 0.002 mg/L for the November survey, which is closer to the suggested guideline value of 0.001 mg/L (suggested to be typical of clear offshore waters). No detections above the lower PQL of 0.002 mg/L were detected.

Total nitrogen concentrations did not exceed the PQL of 0.2 mg/L at any of the sites sampled during the May survey. The PQL was lowered to 0.1 mg/L for the November survey to align with the ANZECC & ARMCANZ (2000) trigger level. No detections above the lower PQL of 0.1 mg/L were measured.

Concentrations of total phosphorous at sites in the May survey did not exceed the PQL or ANZECC & ARMCANZ (2000) guideline trigger value for north-west WA offshore marine environments of 0.01 mg/L. A reduced PQL of 0.005 mg/L for total phosphorous was applied in the November survey and was exceeded, with results still in an acceptable range of 0.01 mg/L–0.012 mg/L.

A summary of the photosynthetic pigment analysis, which is an indicator for plankton, from the surveys is provided in **Section 6.4.3**.

#### 6.3.4.4 Natural Hydrocarbon Seeps

Natural hydrocarbon seep studies in offshore Australia have primarily been in the context of frontier basin exploration and are therefore highly localised and mostly focussed on the NWS region, as Australia's main offshore petroleum province. However, the Browse Basin has been described as the best known area of natural hydrocarbon seepage in the marine environment in Australia (Logan et al. 2010).

In the Browse Basin, within which the Crux project is located, hydrocarbon seeps have been observed at the Cornea oil field and Heywood Shoals on the northern Yampi Shelf, which is approximately 65 km south of the project (Jones et al. 2005; Rollet et al. 2006; Logan et al. 2010). Pockmark formations have been noted in a number of the sub-basins within the Browse Basin (Jones et al. 2007, 2009; Picard et al. 2014; Howard et al. 2016), and were detected during baseline surveys of the project area (as discussed in **Section 6.3.3**) (Fugro 2017a). Pockmarks have been attributed to the expulsion of seawater at the seabed, driven by tidal pumping through the shallow sub-surface and commonly indicate natural hydrocarbon seepage (DIIS 2017). Active expulsion of gas bubbles suggesting seep activity have been observed along the southern flank of the Ashmore Platform, which is approximately 70 km north of the project (Stalvies et al. 2017).

A desktop and field study was undertaken by CSIRO (2017) to characterise the hydrocarbon content of waters and sediments in the Browse Basin in order to identify evidence of hydrocarbon seepage. Sites were selected based on the indication of hydrocarbon seepage by previous studies, as well potential areas of influence relevant to the Prelude and Ichthys facilities. The study recorded evidence of equivocal hydrocarbon seepage in the Browse Basin. This conclusion was primarily based on the presence of hydroacoustic flares within the vicinity of Browse Island and Heywood Shoal. This is in keeping with a survey of the Caswell Sub-basin by Howard et al. (2017) which was unable to conclusively identify hydrocarbon or other fluid seepage, nor detect active seepage, within the sub-basin. Notably, Howard et al. (2017) identified strong currents in parts of the survey area as potentially impeding the detection of seepage in the water column.

### 6.3.5 Sediment Quality

This section provides an overview of the baseline sediment survey conducted within the project area in October/November 2016 (i.e. the 'November Survey', as referred in **Section 6.3.4**) (AECOM 2017). Twenty sample sites were chosen within the in-field development area, 16 which aligned with or were perpendicular to the prevailing tidal current axis and four reference sites located at each corner of AC/LR9 (**Figure 6-2**). Eleven sample sites were selected at 10 km–15 km intervals along the export pipeline corridor to account for existing sediment variability.

In summary, concentrations of metals, hydrocarbons and radionucleotides were generally consistent across all sites, indicating no obvious existing anthropogenic impacts on sediment quality in the area.

#### 6.3.5.1 Metals

No obvious spatial trends were observed for sediment metal concentrations, with slightly elevated concentrations of metals being recorded at various sites within the in-field development area and the south-west end of the proposed export pipeline corridor.

Metal concentrations were detected above the laboratory PQLs for all metals at all sites, with the exception of one reference site in which lead and mercury were below the PQL. However, concentrations across all sites were well below the low levels defined in the Interim Sediment Quality Guideline (ISQG) (ANZECC & ARMCANZ 2000) and/or within values found at reference sites. One exception was nickel which exceeded the concentrations of reference sites at a number of sites along the proposed export pipeline corridor. However, only one site (near the Prelude end of the pipeline corridor) exceeded the ISGQ-Low level of 21 mg/kg with a concentration of 21.9 mg/kg.

#### 6.3.5.2 Hydrocarbons

Detectable levels of petroleum hydrocarbons (TRH and total petroleum hydrocarbon (TPH)) were found at three sites, as well as one polycyclic aromatic hydrocarbon (PAH) (naphthalene) at one site which was detected at concentrations equal to the laboratory PQL. All were interpreted to be within acceptable levels based on currently accepted sediment quality guideline values by Simpson et al. (2013). Oil and grease were detected at all sites above the PQL with no evidence of spatial trends in concentrations.

#### 6.3.5.3 Naturally Occurring Radioactive Material

National Assessment Guidelines for Dredging 2009 (Commonwealth of Australia 2009b) were used to determine acceptability of gross alpha and beta radionuclide concentrations due to the absence of ANZECC & ARMCANZ (2000) guideline trigger values. Whilst the PQL (500 Bg/kg) was exceeded at twenty sites within the in-field development area and export pipeline corridor for gross alpha (560 Bg/kg–1,860 Bg/kg) and one site within the export pipeline corridor for gross beta (640 Bg/kg), the NAGD value of 35,000 Bg/kg was not exceeded at any site.

#### 6.3.5.4 Nutrients

Nitrogen was predominantly present across sites as total Kjeldahl nitrogen (TKN) with a small nitrate plus nitrite component at some sites. TKN concentrations ranged from 210 to 1,040 mg/kg. Concentrations of nitrogen in the form of $NO_x$ across all sites did not exceed the PQL (0.1 mg/kg). There were no spatial patterns evident for nitrogen. Concentrations of phosphorous exceeded the PQL of 2 mg/kg at all sites, ranging from 816 mg/kg to 10,200 mg/kg. These concentrations fell within the ranges found at reference sites, with the exception of three sites located along the export pipeline corridor. There are no ANZECC & ARMCANZ (2000) guideline trigger values for nutrients in sediments.

#### 6.3.5.5 Particle Size Distribution

Particle Size Distribution (PSD) was variable across sites, with an expected higher percentage of fine sediments found at sites in deeper waters. The in-field development area sediment samples were typically characterised by medium to fine sands with variable amounts of silt and clay (5% to 42%). Sediments in the shallower north-east portion of the in-field development area and at a number of sites along the export pipeline corridor were found to be notably coarser, having a higher coarse sand or gravel fraction.

The results of the AECOM (2017) survey broadly support the findings from the Fugro (2017a) survey.

### 6.3.6 Air Quality

No specific information concerning air quality in the project area is available. However, the Crux platform is approximately 190 km from the Kimberley coastline, which itself is a remote and unindustrialised area. Therefore, the air quality is unlikely to be subject to significant anthropogenic effects. Commercial shipping is likely to represent the main source of localised and temporary reductions in air quality. Production facilities in the broader region, such as the Montara FPSO facility (approximately 36 km from the Crux platform), and the Prelude and Ichthys facilities, are also expected to incrementally influence local and regional air quality.

In a regional context, the main contributors to particulate levels are ambient wind-borne dust and smoke from seasonal bush fires that are characteristic across the Kimberley regions. International contributors to reduced air quality in the project area may also include the likes of ‘slash-and-burn’ agricultural methods and other large forest fires in South-east Asian countries (Vadrevu et al. 2014; Kim Oanh et al. 2018).

### 6.3.7 Underwater Noise

Noise in the marine environment is generated by both natural and anthropogenic sources. Natural noise sources include those produced by wind, waves, currents, rain, earthquakes, echo-location and communication noises generated by cetaceans and fish. Natural background noise levels have been recorded as ranging between 90 decibel (dB) to 110 dB (re 1 micropascal (μPa)), representing the typical range for calm to windy conditions, though heavy rain can result in higher noise levels (Shell 2009). Baseline noise monitoring undertaken by INPEX for the Ichthys project, located approximately 164 km to the south-west of the Crux platform, recorded average ambient noise levels of 90 dB (re 1 μPa) under low sea states (INPEX 2010). Baseline noise monitoring for the proposed Barossa project, approximately 713 km north-east of the Crux platform, observed average ambient sound levels ranging between approximately 97 dB and 119 dB (re 1 μPa) (ConocoPhillips 2018). A number of cetacean species were also detected (as discussed in **Section 6.5.6.1**).

The Prelude underwater noise monitoring program, in the northern Browse Basin, also recorded the following natural and anthropogenic features of:

- several regular fish choruses (i.e. schooling fish calling en masse)
- several great whale calls including humpback song, a possible great whale signal, pygmy blue whale signals in late October 2006 and possible minke whale signals
- persistent vessel noise, and
- seismic survey noise, associated with marine seismic survey signals.

The biological noise sources recorded in the Ichthys field were similar and included regular fish choruses, infrequent calls from nearby fish and several whale calls from humpback whales, pygmy blue whales, minke whales and other unidentifiable species (INPEX 2010). Anthropogenic noise sources recorded included low frequency noise from vessels and that generated from seismic surveys being conducted in the region (INPEX 2010).

## 6.4 Ecosystems, Communities and Habitats

### 6.4.1 Marine Regions and Bioregions

The project area is located in the NWMR, on the boundary between the North-west Shelf Transition and Timor Province bioregions (**Figure 6-7**). The majority of the project lies in the Timor Province bioregion, with a small portion of the export pipeline corridor occurring in the Oceanic Shoals bioregion. The NWMR has a large area of continental shelf and continental slope, with a range of bathymetric features such as canyons, plateaus, terraces, ridges, reefs, shoals and banks (Woodside 2014). The in-field development area and export pipeline corridor fall between the key bathymetric features of these two bioregions; the Bonaparte Depression (to the east) and the continental shelf slope (to the west) (DEWHA 2008a).

The project is distant from other significant features within the NWMR typically associated with reefs and islands, as described in **Section 6.4.5**. The NWMR also supports internationally significant breeding and feeding grounds for a number of threatened and migratory marine fauna species (DEWHA 2008a). Results of an EPBC Protected Matters Database search for the in-field development area and export pipeline corridor are presented in **Section 6.5**.

While the project area is located wholly within the NWMR, the area of influence extends into the North Marine Region (NMR). The NMR encompasses the entire NT coastline and the Queensland coastline west of the Cape York Peninsula. The region is typified by a wide continental shelf with shallow water depths typically less than 70 m (DSEWPaC 2012a). The seafloor of the NMR is characterised by canyons and terraces, and features the Pinnacles of the Bonaparte Basin and complex and morphology of the Van Diemen rise (as described in **Section 6.4.7**).

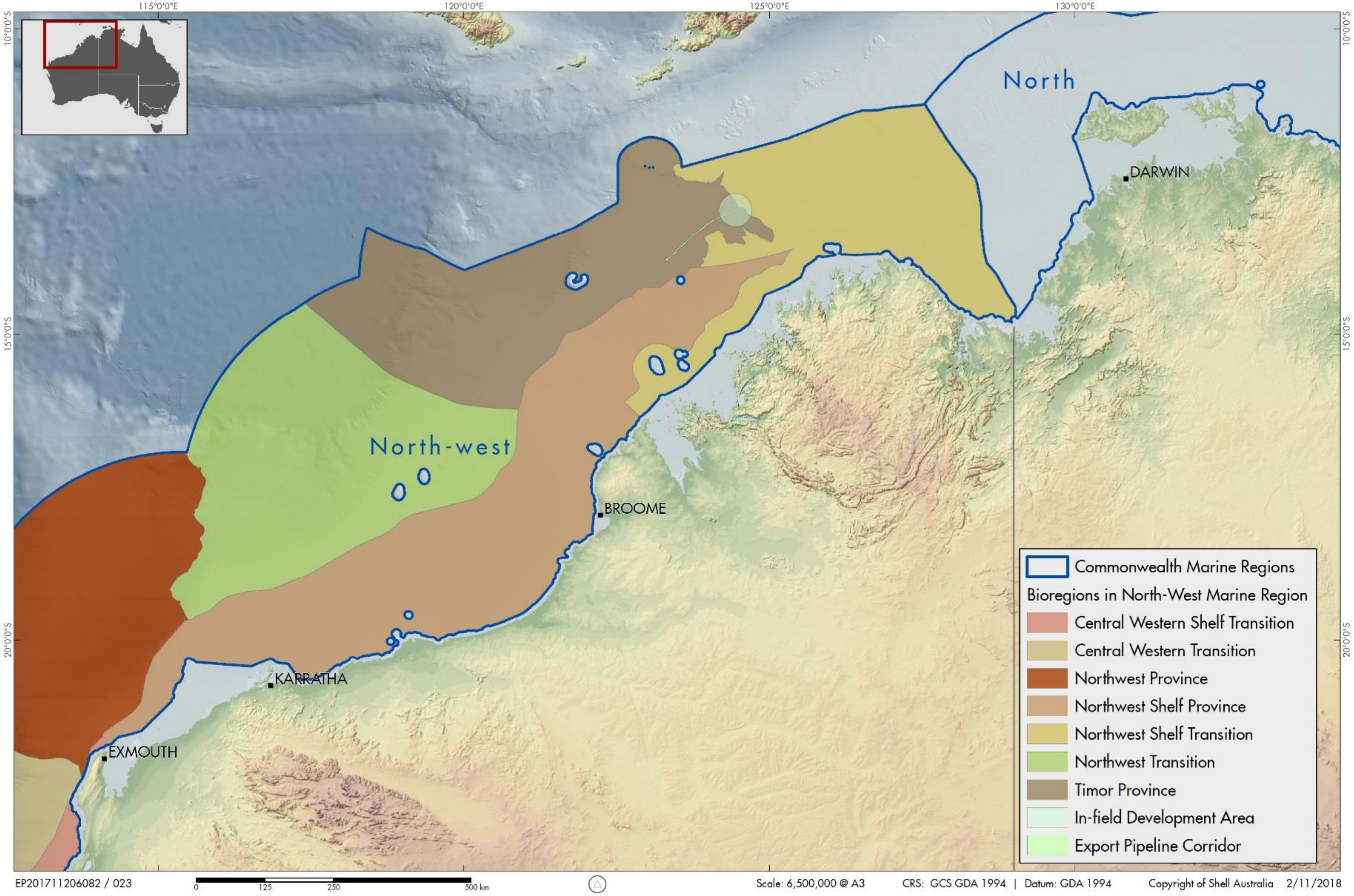



Figure 6-7: Marine Regions and Bioregions

### 6.4.2 Benthic Communities

#### 6.4.2.1 Regional

Macrobenthos are organisms which live within (infauna) or on (epifauna) the seabed sediments. In the shallower coastal waters of the continental shelf, and on reefs and shoals/banks in less than 50 m water depth, communities of benthic epifauna are abundant and diverse. However, seafloor communities in deeper waters, such as those found within the project area, are generally expected to be less abundant and diverse. Notably, the absence of hard substrate at depth in areas of soft sediment is also considered a limiting factor for the recruitment of epifauna (Shell 2009).

A benthic habitat survey undertaken in the vicinity of Prelude provides an indication of the regional macrobenthos abundance and community composition. Macrobenthos composition was recorded as being similar across the survey area while abundance was found to be consistently low (an average of 7.9 individuals per sample grab) (Shell 2009). While individuals were identified from nine different Phyla, approximately 80% of individuals across the survey area were identified as Annelid worms (Shell 2009). Species from three classes of polychaete worm and mud shrimps (Crustacea) were also dominant.

Other surveys in the region include seabed habitat surveys for the Ichthys Gas Field Development Project, Montara Development Project, Browse Upstream Development and Bonaparte LNG Project. The seabed within the Ichthys field (235 m to 275 m), approximately 164 km south-west of the in-field development area, was characterised by bare substrates with heavily rippled sand, which is indicative of strong near-seabed currents and mobile sediments that are unfavourable towards the development of diverse epibenthic communities (INPEX 2010). Few epibenthic organisms were recorded within the Ichthys field. A low cover of epibenthic fauna, comprising filter feeding communities with sponges, gorgonians, soft corals, hydroids, bryozoans, fan worms and other polychaetes, was observed within the broader exploration permit area where the seabed comprised a pavement reef with a sand veneer (INPEX 2010). The infauna within the Ichthys field was dominated by polychaete worms and crustaceans, which accounted for approximately 70% of the infaunal assemblage (INPEX 2010).

The benthic habitats in the Montara development project area, approximately 36 km north-east of the Crux platform, were characterised by homogenous, flat, featureless soft sediment with low relief ripples displaying evidence of bioturbation (PTTEP 2017). The sparsely distributed epifauna assemblage supported hydroids, octocorals (soft corals, gorgonians and seapens), black corals and ascidians. The macrobenthic faunal assemblages were generally low and patchy in abundance, with the dominant species being polychaete bristleworms (abundance of approximately 40 to 60%) and crustaceans (e.g. shrimps, crabs) (approximately 13 to 19%) (PTTEP 2017).

The deep-sea seabed (400 m to 600 m) within the Browse development area, approximately 265 km south-west of the Crux platform, was observed as comprising fine sand and silt with epibenthic fauna limited to isolated individual bryozoan colonies, brittlestars and basketstars, and sea anemones (Woodside 2014). The most abundant infauna recorded were polychaete bristleworms, accounting for 53.4% of all infaunal assemblages (Woodside 2014).

Benthic habitat in the GDF Suez (now Engie/Neptune Energy) Bonaparte Basin retention lease areas (approximately 440 km east of the Crux platform, in water depths 80 m to 100 m) was recorded as soft sediments with epifauna and sessile benthos generally being sparse and characterised by a limited number of common and widespread taxa (GDF Suez 2011). Infaunal communities were also observed to be typical of soft sediment habitat and dominated by polychaete worms (GDF Suez 2011).

#### 6.4.2.2 Crux Project Area

Camera observation and benthic grab surveys for benthic fauna and community characterisation were undertaken in the project area by Fugro (2017a) and AECOM (2017). The camera survey was conducted in April/May 2017 using a towed mounted camera and video camera system. A total of 25 camera transects were surveyed; 10 in the in-field development area, 12 along the export pipeline corridor, and an additional two along an alternative export pipeline route (**Figure 6-2**). Four additional transect sites were intended for inclusion but poor visibility at the seabed precluded the use of three of these. Visibility was typically poorer at the Prelude end of the export pipeline corridor due to finer sediments. Grab sampling sites for the sediment benthic fauna analysis by AECOM (2017) were the same 31 sites as for the sediment quality assessment summarised in **Section 6.3.5** (refer **Figure 6-2**) (AECOM 2017). Triplicate samples were made at reference sites resulting in a total of 39 samples being collected using the benthic grab.

In summary, the benthic surveys observed a very low macrobenthic fauna abundance in the project area (AECOM 2017). The dominant phyla were Annelida, Mollusca, Porifera and Arthropoda, as expected for the region.

Eight benthic habitats were identified within the project area based on a hierarchical benthic habitat classification scheme which considered geomorphological structure and comprising sediments (Fugro 2017a). **Figure 6-8** shows the distribution of the benthic habitats across the project area while **Figure 6-9** provides photographs representative of these habitat types. A detailed summary of the benthic habitats is provided in **Table 6-2** (Fugro 2017a). The amount of hard substrate present appeared to have the greatest effect on the composition of the benthic community present (Fugro 2017a). **Figure 6-8** shows that the majority of the benthic habitat within the project area was characterised by burrowing macrofauna communities or no macrobiota (<10% cover).Sediment types observed on the camera varied across the survey area. Muddy sand was observed on the video to the south of the survey area at the Prelude end of the export pipeline route, while gravelly sand with hard substrate was observed in the shallower areas of the in-field development area. This was broadly consistent with the geophysical data interpretation which identified the predominant sediment type as silty sand at the in-field development area, with sand being the predominant sediment type along the export pipeline route. Overall epifaunal abundance was low with some habitats having little to no visible fauna. Most habitats had low faunal abundance with a few characterising taxa.

Sampling of the benthic fauna within the sediments identified 457 individual infauna (AECOM 2017). Of the 457 individuals collected, 11 major phyla and sub-phyla were identified. The dominant phyla were Annelida (approximately 37%), Mollusca (approximately 24%) and Porifera (approximately 11%). A summary of the benthic fauna identified is shown in **Table 6-3**. There were no evident spatial trends in benthic infauna based on sediment physicochemical attributes. Replicate samples at reference sites, and comparisons between sites with similar sediments, indicated high variability between samples. The patchy distribution was described as typical of benthic infauna for soft sediment habitats (AECOM 2017).

As shown by **Figure 6-8**, the outcropping reef area (in the north-eastern section of the in-field development area) were observed to support filter feeders and burrowing macrofauna, with areas generally devoid of macrobiota. The key characterising fauna were sea whips, branching soft coral, sponges and hydroids (**Table 6-2**). Representative photographs of the benthic habitats supported by the reef feature are shown in **Figure 6-10**. The benthic habitats do not support highly diverse benthic communities, such as those characteristic of shoals and banks within the region (**Section 6.4.4**).

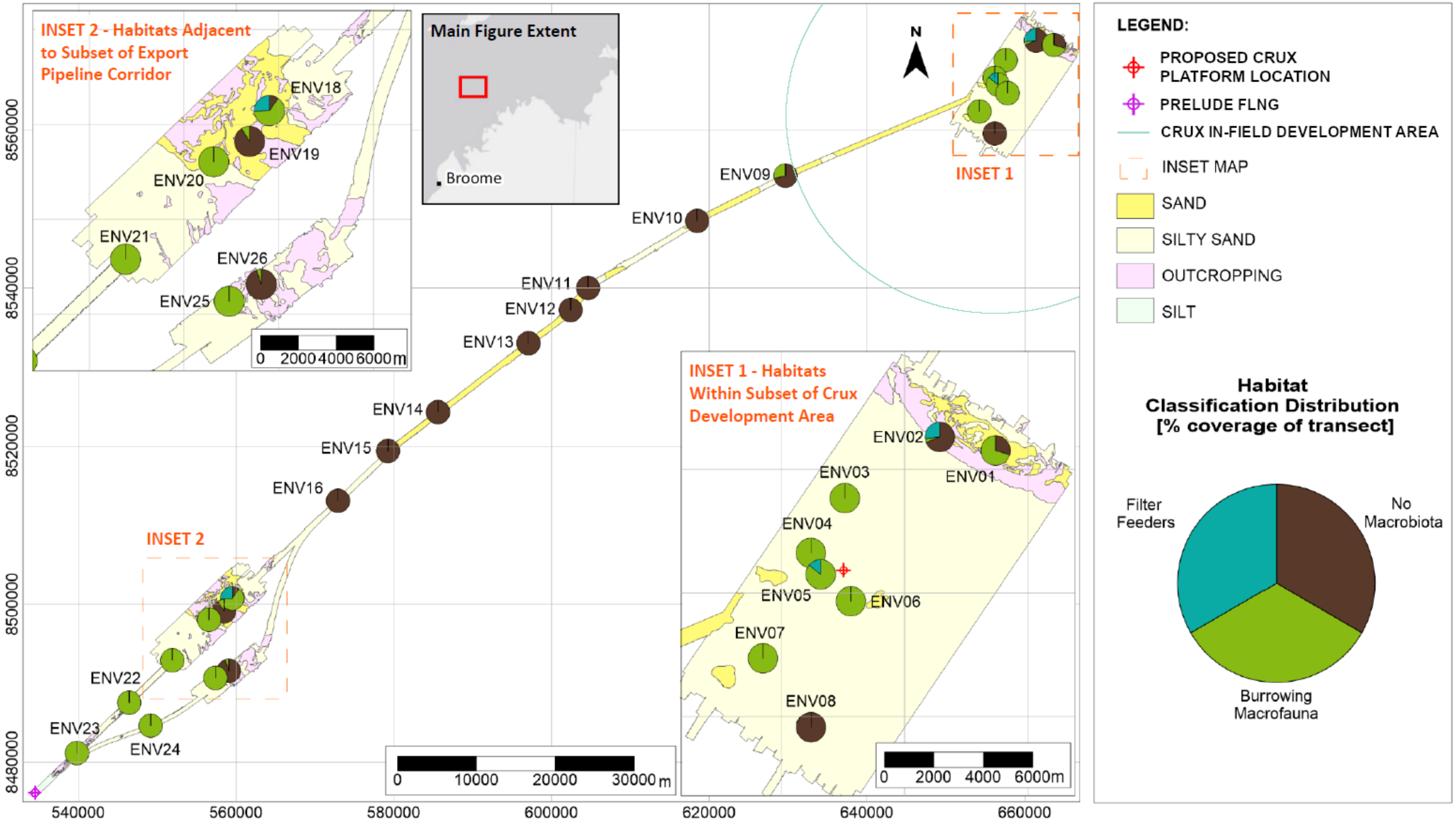
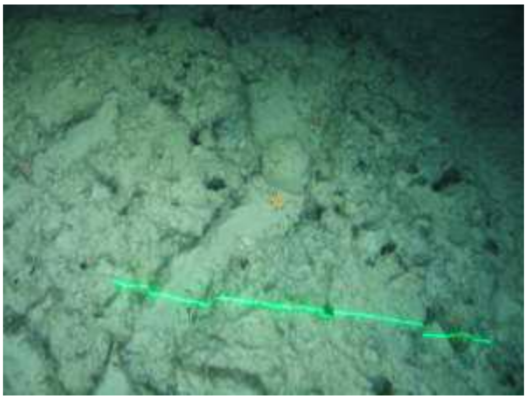
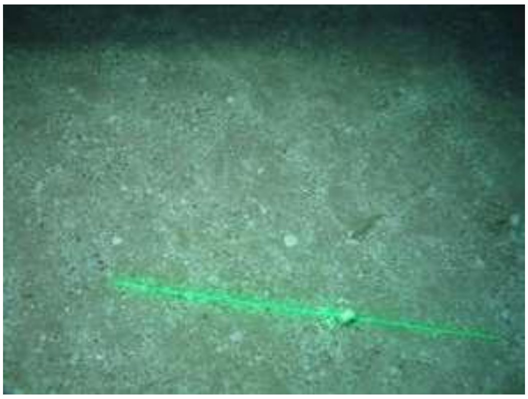


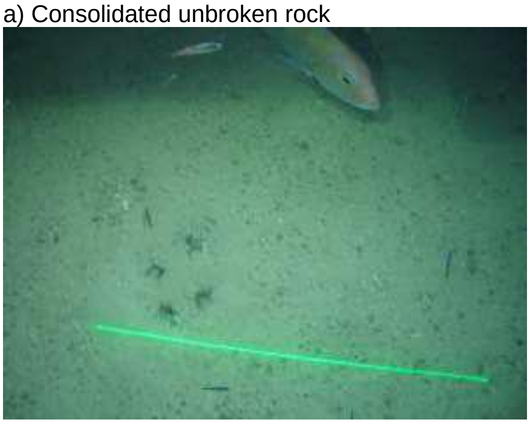

Figure 6-8: Benthic Habitat Classification and Fugro (2017a) Sample Sites within the Project Area



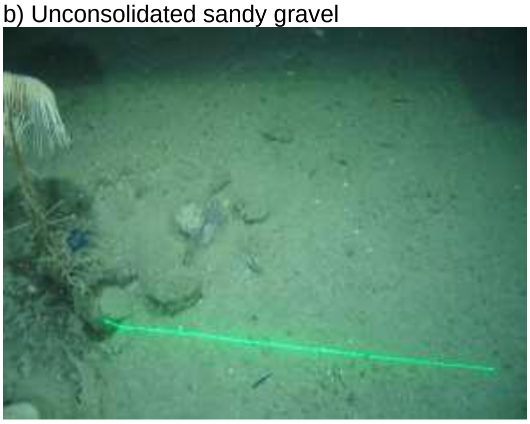
a) Consolidated unbroken rock



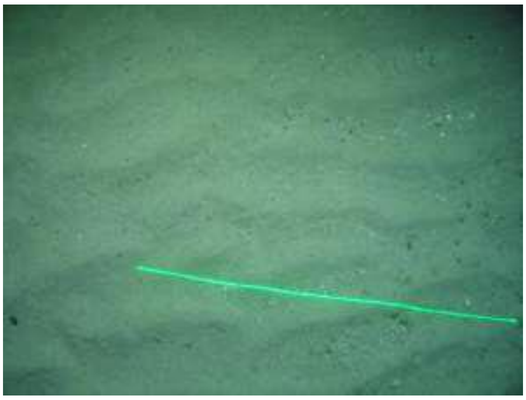
b) Unconsolidated sandy gravel



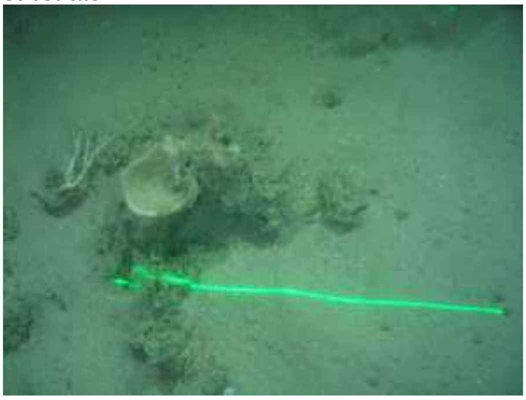
c) Unconsolidated gravelly sand



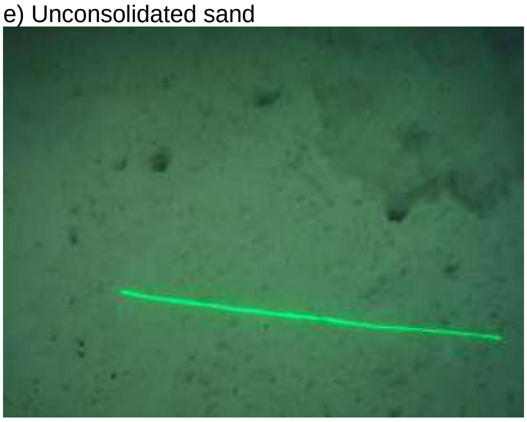
d) Unconsolidated gravelly sand over hard substrate



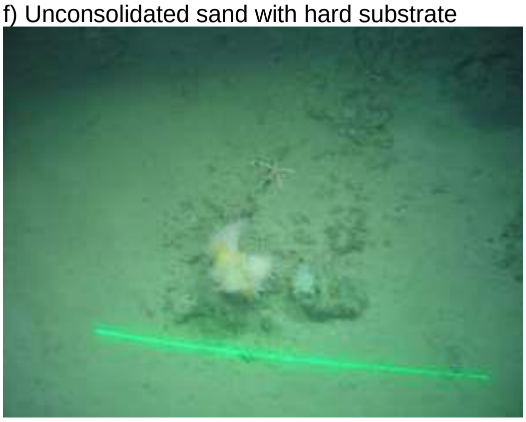
e) Unconsolidated sand



f) Unconsolidated sand with hard substrate



g) Unconsolidated muddy sand

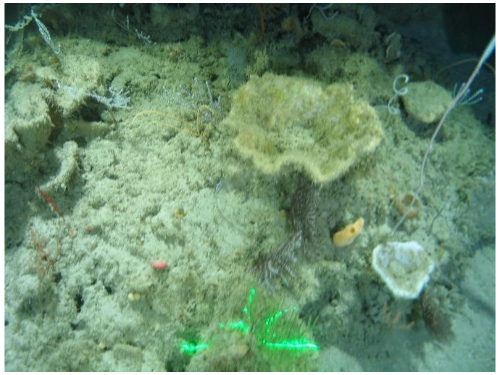


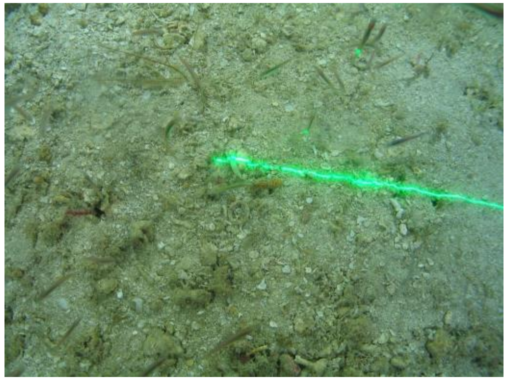
h) Unconsolidated muddy sand with hard substrate

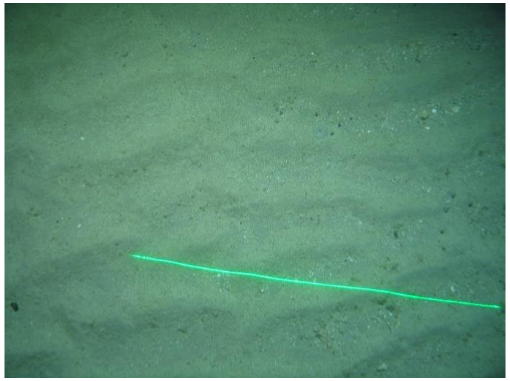
Figure 6-9: Photographs of the Benthic Habitats Identified in the Project Area

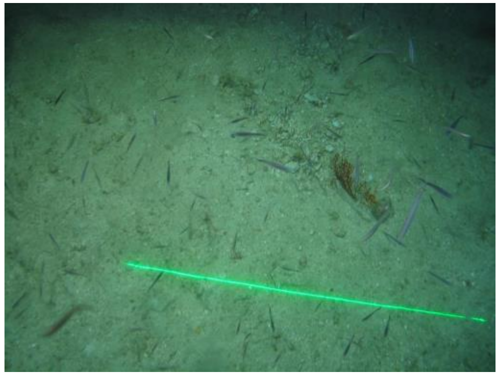
Table 6-2: Benthic Habitats within the Project Area

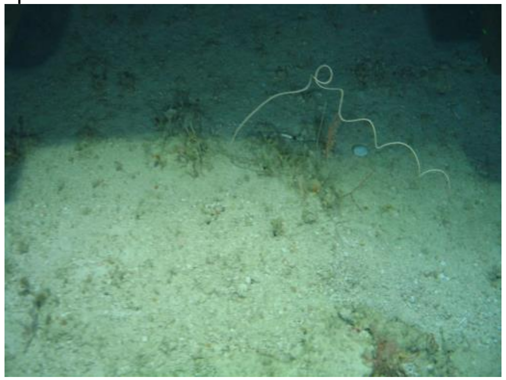
| Level 1 | Level 2 | Level 3 | | | | Location |
|---|---|---|---|---|---|---|
| **Substrate Type** | **Particle Size** | **Sediment Particle Size** | **Sediment Description** | **Profile** | **Characterising Fauna** | |
| Consolidated | Rock | Rock (unbroken) | Reef with sand veneer, high relief | High | Burrows, soft coral (Alcyonaria), sponge (Porifera), sea anemone (Actiniaria), branching coral (Alcyonacea) | Export pipeline corridor |
| | | | Reef with sand veneer, medium relief | Medium | Sea whips (Alcyonacea), branching soft coral (Alcyonacea), sponge (Porifera) | In-field development area (outcropping reef area), export pipeline corridor |
| | | | Reef with veneer of sediment, low relief | Low | Hydroids (Hydrozoa), sponge (Porifera), branching coral (Alcyonacea) | In-field development area (outcropping reef area), export pipeline corridor |
| Unconsolidated | Gravel | Sandy gravel | Sandy gravel | Flat | Sparse to no fauna | Export pipeline corridor |
| | | Gravelly sand | Gravelly sand | Flat to small ripples | Soft coral (Alcyonacea), hydroids (Hydrozoa) | In-field development area, export pipeline corridor (alternate route only) |
| | | | | | Faunal burrows | Export pipeline corridor |
| | | | | | Sparse to no fauna | Export pipeline corridor |
| | | Gravelly sand over substrate | 1 – 49% reef | Flat | Sea whips (Alcyonacea), hydroids (Hydrozoa), sponge (Porifera) | In-field development area, export pipeline corridor |
| | Sand | Sand | Sand | Flat to medium ripples | Faunal burrows | In-field development area, export pipeline corridor |
| | | | | | Sea anemone (Actiniaria), tubular glass sponges (Porifera), sea urchin (Echinoidea) | In-field development area |
| | | | | | Sparse to no fauna | Export pipeline corridor |
| | | Sand with hard substrate | 1 – 49% reef | Flat | Sponges (Porifera), crinoids (Crinoidea), faunal burrows | In-field development area, export pipeline corridor |
| | | | Volcanic rock | Small to medium waves | Sparse to no fauna | Export pipeline corridor |
| | Mud | Muddy sand | Muddy sand | Flat | Faunal burrows | In-field development area, export pipeline corridor |
| | | Muddy sand with hard substrate | 1 – 24% reef | Flat | Sponges (Porifera), faunal burrows | Export pipeline corridor |


a) Unbroken rock substrate with sand veneer – with sponges, hydroids, bryozoan, sea whips


b) Gravelly sand – with hydroids and small fish species


c) Sand forming sand waves – with no visible fauna


d) Reef rubble with sand veneer – with sea fan and small fish


e) Reef rubble with sand veneer – with sea whip and hydroids

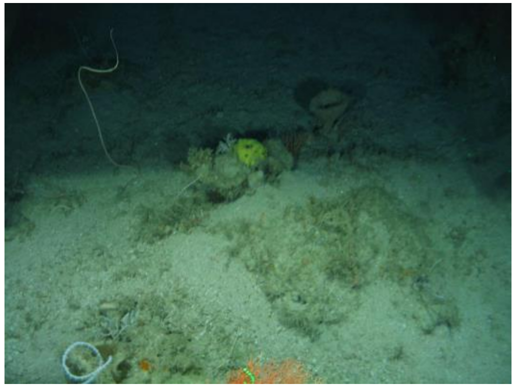

f) Reef with sand veneer – with sea ship, sea fan, sponges, hydroids

Figure 6-10: Photographs of the Benthic Habitats Associated with the Outcropping Reef Feature

Table 6-3: Benthic Fauna Abundance from Sediment Grab Samples

| Phylum | Number of Individuals | % Total | Number of Morphospecies | % Total |
|---|---|---|---|---|
| Porifera | 50 | 11.0 | 8 | 5.2 |
| Nemertea | 8 | 1.8 | 2 | 1.3 |
| Annelida (Echiura) | 2 | 0.4 | 2 | 1.3 |
| Annelida (Sipunculida) | 31 | 6.8 | 10 | 6.5 |
| Annelida (Polychaeta) | 137 | 30.0 | 55 | 36.0 |
| Mollusca | 108 | 23.6 | 18 | 11.8 |
| Bryozoa | 5 | 1.1 | 3 | 2.0 |
| Nematoda | 16 | 3.5 | 4 | 2.6 |
| Arthropoda (Crustacea) | 70 | 15.3 | 37 | 24.2 |
| Echinodermata | 29 | 6.4 | 13 | 8.5 |
| Chordata | 1 | 0.2 | 1 | 0.7 |
| **Total** | **457** | **100** | **153** | **100** |

### 6.4.3 Plankton

Plankton refers to generally passively, mobile, single-celled organisms that are present within the water column. Forms include a highly diverse mix of phytoplankton and zooplankton, ranging in size from micrometres to centimetres that fulfil a diverse range of ecological roles.

Plankton distribution is often patchy and linked to localised and seasonal productivity that produces sporadic bursts in phytoplankton, zooplankton and tropical krill production (DEWHA 2008a). Fluctuations in abundance and distribution occur both horizontally and vertically in response to the tidal cycles, seasonal variation (light, water temperature and chemistry, rainfall, currents and nutrients) and cyclonic events. In general, the mixing of warm surface waters with deeper, more nutrient-rich waters (i.e. areas of upwelling) generates phytoplankton production and zooplankton blooms.

#### 6.4.3.1 Regional

Previous surveys undertaken in offshore marine waters near the Prelude location concluded that phytoplankton was highly diverse but low in abundance (Shell 2009). However, phytoplankton abundance is likely to be seasonal with higher densities occurring during the spring and summer (Shell 2009). Key groups identified near Prelude included dinoflagellates (Dinophyceae), diatoms (Bacillariophyceae) and Prasinophyceae. The most abundant species included *Prasinophyte sp.* (Prasinophyceae); *Gyrodinium sp.* and *Heterocapsa sp.* (Dinophyceae); *Pseudonitzschia sp.*, *Cylindrotheca closterium*, *Chaetoceros sp.*, *Thalassionemafrauenfeldii* and *Nitzschia longissima* (Bacillariophyceae) (Shell 2009). The Prelude EIS also noted that phytoplankton in the wider NWS region is similar to that observed in the Prelude location with relatively high diversity in certain groups recorded such as diatoms, dinoflagellates and coccolithophorids (Hallegraeff and Jeffrey 1984; Hallegraeff 1984, cited in Shell 2009). Zooplankton assemblages within the Prelude location were primarily dominated by copepod species (Shell 2009). However, overall densities of crustacean assemblages were relatively low and typical of low nutrient open ocean environments in the region.

The phytoplankton and zooplankton assemblages in the Prelude location were consistent with the results of a survey in the Timor Sea for the proposed Sunrise Gas

Project (approximately 550 km north-west of the Crux platform), which also found phytoplankton abundance to be low and zooplankton samples to be low in abundance but high in diversity of species (BBG 2002).

#### 6.4.3.2 Crux Project Area

As part of the baseline water quality surveys undertaken for the Crux project (see **Section 6.3.4**), chlorophyll concentrations were measured as an index of phytoplankton biomass (AECOM 2016, 2017). Analysis was undertaken for total chlorophyll, chlorophylls 'a', 'b' and 'c', and phaeophytin. The ratio of the three forms of chlorophyll (‘a’, ‘b’ and ‘c’) is used as an indicator of the composition of the phytoplankton assemblages.

For the four parameters analysed (Chlorophyll a, b, c and phaeophytin), no sites registered a result above the laboratory PQL of 0.0001 mg/L (0.0002 mg/L for phaeophytin) in the November survey (AECOM 2016). This is marginally different to the May survey results, where concentrations of chlorophyll ‘a’ were measured above the PQL at seven sites within the in-field development area (AECOM 2017). All detections of total chlorophyll for both surveys were very low with the measured concentration of total chlorophyll at all sites being 0.0001 mg/L, with the exception of one site in the May survey which returned a value of 0.0002 mg/L. These results are below the ANZECC & ARMCANZ (2000) trigger levels for offshore marine waters of Northern Australia (0.0005 – 0.0009 mg/L). The lower of these two values is typical of clear coral dominated waters (e.g. Great Barrier Reef), while higher values are typical of turbid macrotidal systems (e.g. NWS of WA) (ANZECC & ARMCANZ 2000).

In conclusion, photosynthetic pigments in surface waters within the project area were generally low and typical of clear tropical open water environments. These results suggest very little seasonal variation in photosynthetic pigments in the surface waters between the two surveys.

### 6.4.4 Shoals and Banks

There are a large number of shoals and banks within the Browse Basin and open offshore waters off northern Australia, including those shown in **Figure 6-11**, that have recognised environmental value. An understanding of these features has been gained from the Big Bank Shoals study (Heyward et al. 1997), PTTEP surveys initiated in response to the Montara incident (Heyward et al. 2010; Heyward et al. 2012) and the regional shoals and shelf assessment undertaken by AIMS for the Barossa Area Development project (Heyward et al. 2017b). Other studies which have contributed to the scientific understanding of these features include the INPEX Ichthys surveys, those within the surrounds of the Barossa offshore development area and the baseline studies for the Crux project (as discussed further below).

#### 6.4.4.1 Ecological Importance

The shoals and banks within the Crux project area, and the Timor Sea more broadly, are of recognised environmental value. The benthic habitats and associated fauna assemblages are highly diverse compared to the surrounding relatively deep and bare seabed which constitutes the majority of the outer continental shelf in the region. These isolated “islands” of biodiversity may act as important sources of larvae of important taxa such as fish and corals, which may be advected considerable distances. This supply of larvae may enhance recovery of banks, shoals and reefs following disturbances such as cyclones, fishing and coral bleaching events, and hence may play a role in regional ecosystem resilience (Wahab et al. 2018).

The shoals/banks support many of the same species found on emergent reef systems of the Indo West Pacific region such as Ashmore Reef, Cartier Island, Seringapatam Reef and Scott Reef (Heyward et al. 2017b). This indicates a high level of ecological connectivity among the reef systems and between the shoals/banks. This is further supported by an analysis undertaken by AIMS which compared benthic habitat community data from a number of shoals/banks within the Timor Sea and Bonaparte Gulf region. The analysis showed that neighbouring shoals and banks frequently share many attributes in terms of benthic community composition and species (Heyward et al. 2017a).

Corals, such as those supported on shoals/banks, are recognised as a key element of reef ecosystems as they provide the structural framework for reef growth (i.e. they are a habitat-forming species), as well as providing important habitat and food source for a vast range of marine organisms, including species of conservation significance (Depczynski et al. 2017). Corals are recognised as providing high ecological value to the marine environment. For example, extensive coral loss can result in declines in habitat and topographical complexity (Sheppard et al. 2002; Graham et al. 2007), which are critical for sustaining high diversity of reef fishes and other reef-associated organisms (Wilson et al. 2006; Pratchett et al. 2009b) (cited in Pratchett et al. 2011).Environmental monitoring following the Montara oil spill has indicated some components of the biological communities of the banks and shoals in the Timor Sea are dynamic, with changes in habitats (e.g. seagrass distribution) and fish assemblages over time. The apparently healthy marine communities observed during the post-Montara monitoring may indicate these communities were not significantly exposed to spilled oil or were resilient to oil contamination; the lack of long-term monitoring data (including baseline data) makes interpretation of monitoring results difficult.

There is some evidence of fishing pressure (particularly illegal fishing such as shark finning) on the banks and shoals in the Timor Sea. Heyward et al. (2017) suggested that the low abundance of highly prized finfish and sharks, indicates banks and shoals are subject to some fishing pressure despite the long distances from ports. Fishing at banks and shoals may include both subsistence and commercial fishing, potentially providing food and income.

While the benthic communities on each shoal/bank reveal a degree of connectivity, it is acknowledged that they may vary in the abundance and diversity of dominant benthic species, with subsets of species featuring more prominently on some than others (Heyward et al. 2017b). This variability may reflect different disturbance events (e.g. cyclones, storm damage and coral bleaching) and recruitment histories, as well as potentially different ecosystem trajectories (Heyward et al. 2017b).

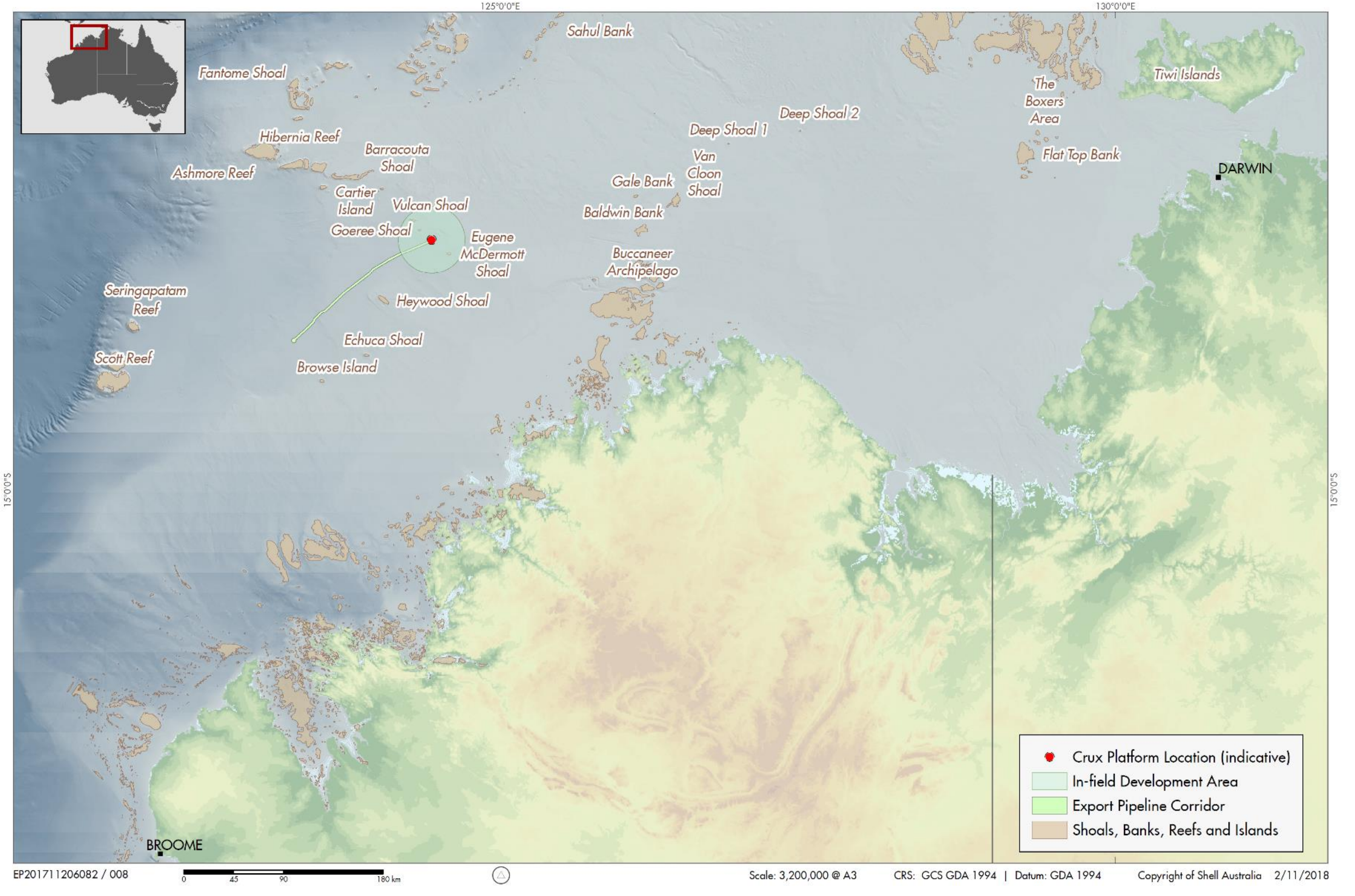



Figure 6-11: Shoals and Banks, and Offshore Islands/Reefs within the Area of Influence of the Crux Project

Shoals within the boundary of the Crux in-field development area are surrounded by a 1 km buffer within which no activities will take place. These shoals are described in more detail below and include (**Figure 5-3**):

- Goeree Shoal – located within the in-field development area with a 1 km exclusion buffer around the shoal, approximately 13 km north-west of the Crux platform,
- Eugene McDermott Shoals – located within the in-field development area with a 1 km buffer, approximately 18 km south-east of the Crux platform, and
- Vulcan Shoal – located within the in-field development area with a 1 km buffer, approximately 22 km north-west of the Crux platform.

Shoals in the region beyond the Crux in-field development area include:

- Barracouta Shoals – located approximately 63 km north-west of the Crux platform,
- Heywood Shoals – located approximately 67 km south-west of the Crux platform and approximately 21 km from of the export pipeline corridor at the closest point, and
- Echuca Shoals – located approximately 117 km south-west of the Crux platform and approximately 53 km north of the export pipeline corridor.

The shoals closest to the project area have been subject to comprehensive survey by AIMS following the 2009 Montara oil spill (Heyward et al. 2012). The survey involved multibeam swath mapping and towed video and digital stills along a number of transects across the shoals. Stereo Baited Remote Underwater Video Stations (BRUVs) were deployed at sample sites in order to provide a representation of the benthic and pelagic communities of the wider shoal area. Shell and INPEX also commissioned AIMS to undertake a detailed survey of the benthic habitats and fish communities at Heywood Shoal and Echuca Shoal (Heyward et al. 2017a). The survey adopted the same methods and sampling locations that were first applied on these shoals as part of a post-Montara impact assessment. The topography, characterising benthic habitats and pelagic communities of the shoals are described below.

### 6.4.4.2 Shoals within the Crux In-field Development Area

#### Goeree Shoal

Goeree Shoal is the closest bank or shoal to the Crux platform that has been named by the Australian Hydrographic Office, lying approximately 13 km north-west of the Crux platform. Goeree Shoal lies within the boundary of the Crux in-field development area, and Shell has applied a 1 km buffer around the shoal within which no activities will take place. The bathymetric features of Goeree Shoal are consistent with the patterns observed at other shoals and banks in the region, although Goeree Shoal is smaller than Vulcan and Eugene McDermott shoals, which also lie within the Crux in-field development area. Goeree Shoal rises abruptly from the surrounding seabed, with steep sides of the shoal rising from approximately 170 m to < 40 m (**Figure 6-12**). The top of the shoal forms a plateau ranging from approximately 20 to 40 m water depth. The western part of the plateau is relatively shallow (**Figure 6-12**) and is characterised by hard coral communities (**Figure 6-13**). Growth of these hard corals may account for the relatively shallow local bathymetry in this part of the shoal. At a coarse scale (> 500 m), the surface of Goeree Shoal is relatively smooth. At finer scales (10 m to 100 m) the bathymetry is rugose, which reflects the complexity of the benthic habitats found on Goeree Shoal.

Like other banks and shoals in the region, Goeree Shoal is understood to have been formed through in situ biogenic production of sediments, particularly calcareous green algae in the genus *Halimeda* spp. Coring in shoals and banks in the region has identified extensive deposition of carbonates of biogenic origin (Heyward et al. 1997). Geological assessment by Saqab and Bourget (2015) indicates the banks and shoals features developed primarily in phase with repeated changes in sea level, providing further evidence for localised sediment production generating the banks and shoals.

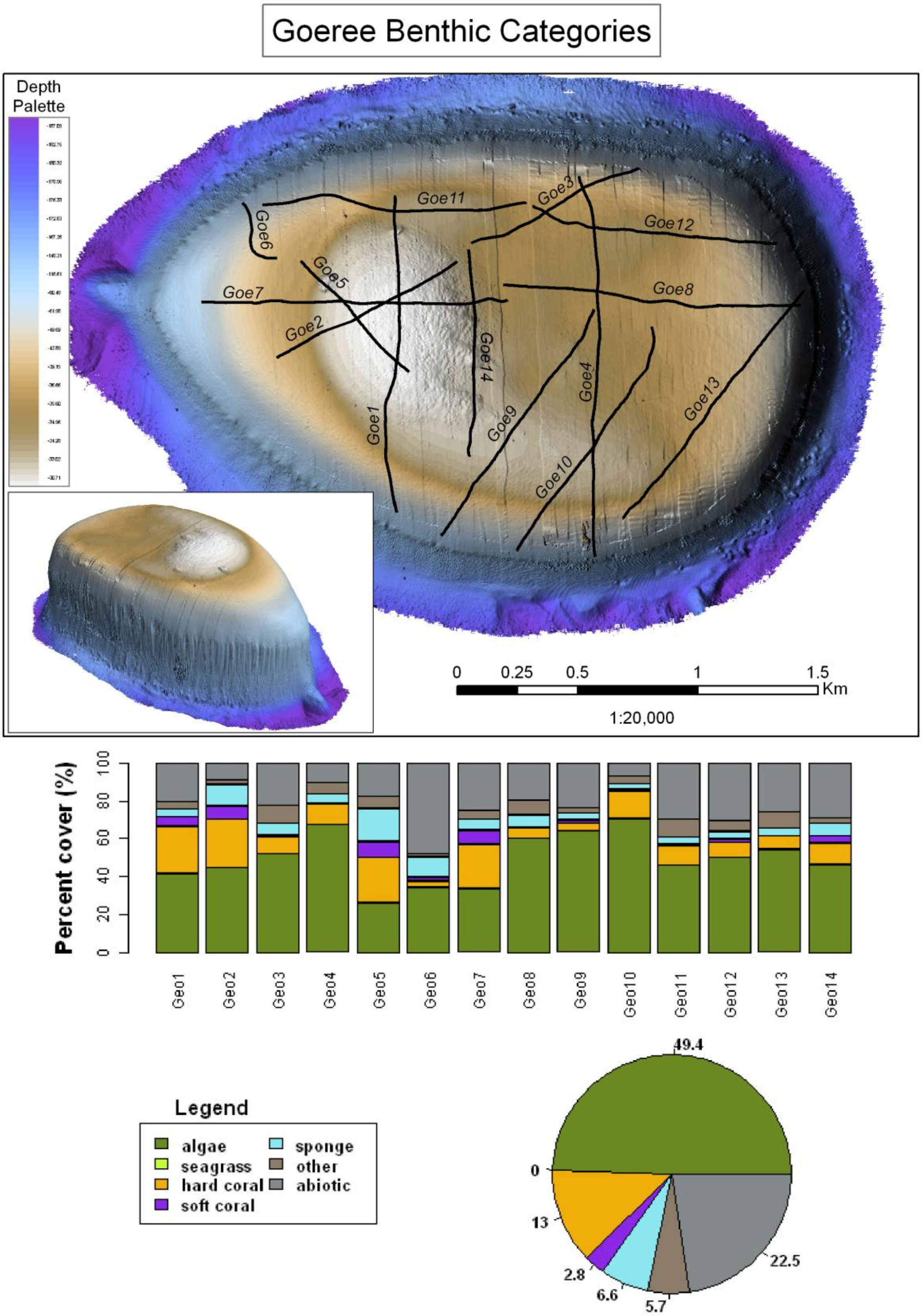



Figure 6-12: Goeree Shoal Morphology, Depth and Abundance of Major Benthic Groups derived from Multibeam Echo Sounder and Towed Video Surveys (from Heyward et al. 2012)

Sediments within and around Goeree Shoal are characterised by sand and gravel fractions, which is coarser than the silty sands around the Crux platform (Fugro 2017a). The relatively coarse characteristics of the sediments may be the result of the relatively young geological age of locally produced biogenic sediments (e.g. hard coral rubble or calcareous *Halimeda* spp. fragments) and potential exposure to relatively fast surface currents that may re-suspend fine sediments. Data presented in Heyward et al. (2017) indicates sediments at Goeree Shoal are generally coarser than at Vulcan or Eugene McDermott shoals.

Benthic habitats at Goeree Shoal (**Figure 6-13**) are broadly similar to other shoals in a similar depth range in the region. Habitats in < 30 m of water are characterised by consolidated reef (and associated turfing algae), sand, hard coral, algae and unconsolidated reef (Heyward et al. 2017b). The relative abundances of these habitats change with increasing depth, with algae and hard corals decreasing in relative abundance in waters around Goeree Shoal between 30 and 60 m depth (Heyward et al. 2012, Heyward et al. 2017b). This is likely to be the result of photosynthetically active radiation decreasing as water depth increases, limiting the depth range of photosynthetic organisms such as algae, seagrass and zooxanthellate corals. Substrate types appear to be highly spatially correlated with habitats (**Figure 6-14**). Unconsolidated reef (such as rubble from *Halimeda* and hard coral) increases with water depth. Substrate types are correlated with habitat types (**Figure 6-14**).

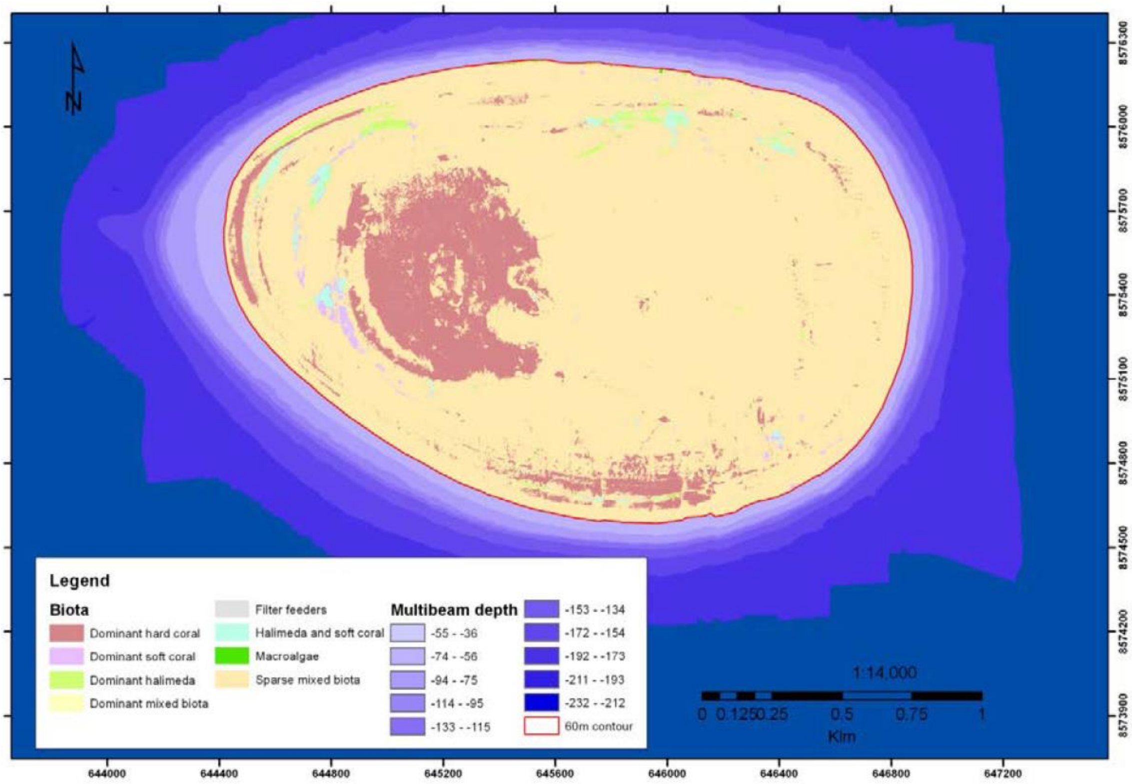



Figure 6-13: Composite Modelled Benthic Habitats of Goeree Shoal (from Heyward et al. 2012)

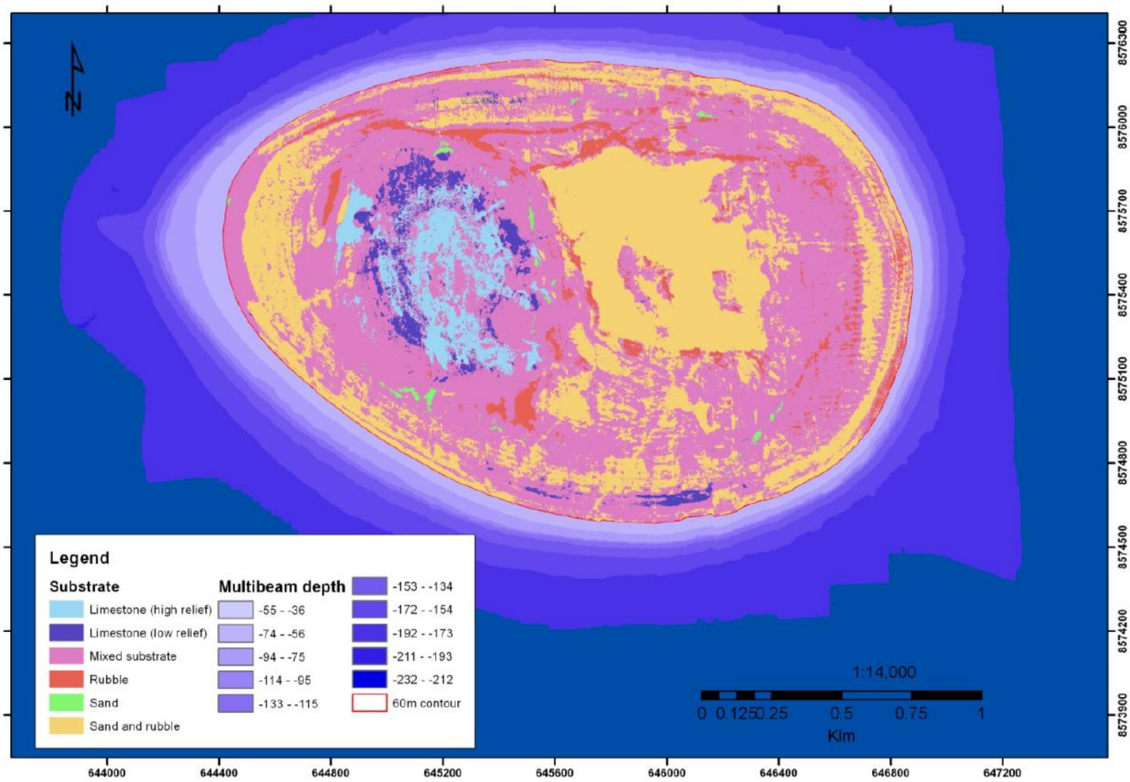



Figure 6-14: Composite Modelled Substrate Types of Goeree Shoal (from Heyward et al. 2012)

The relatively complex benthic habitats of Goeree Shoal support a diverse fish assemblage compared to the surrounding deeper seabed habitat surrounding the shoal. Sampling using BRUVs following the Montara oil spill indicated the fish assemblage at Goeree Shoal was diverse, with significantly greater fish abundance and diversity associated with the hard coral habitat found on the western part of the shoal (Heyward et al. 2012). The fish assemblage within this part of the shoal was characterised by species associated with coral habitat, including species of grouper (Serranidae), damselfish (Pomacentridae) and wrasses (Labridae) (Heyward et al. 2012). The deeper parts of the shoal classified as sparse mixed biota, where hard coral cover is low, were characterised by wrasses (Labridae), houndsharks (Triakidae) and dartfish (Ptereleotrinae) (Heyward et al. 2012). Sparse mixed biota was the most common habitat found on Goeree Shoal (**Figure 6-13**).

Analysis of repeated sampling using BRUVs at several of the banks and shoals in the Timor Sea indicated that the cumulative species curves typically do not reach an asymptote. This indicates that these assemblages are likely to be more diverse than has been observed to date (Heyward et al. 2012, 2017).

**Eugene McDermott Shoal**

Eugene McDermott Shoal lies within the boundary of the Crux in-field development area, approximately 18 km south-east of the Crux platform. Shell has applied a 1 km buffer around Eugene McDermott Shoal within which no activities will take place. Like Goeree Shoal, Eugene McDermott Shoal rises abruptly from the seabed (**Figure 6-15**). The surface of the shoal reaches to approximately 20 m water depth in the shallowest part of the shoal. The plateaued surface of the shoal is somewhat more domed in shape than some other shoals in the region; the gradient from the shallowest part of the shoal to approximately 100 m water depth is less steep than similar shoals in the region. The sides of the shoal become steeper beyond approximately 100 m water depth, with a similar gradient from this depth to the surrounding continental shelf (< 150 m). The relatively shallow domed part of the shoal is characterised by a high cover of hard coral habitat (**Figure 6-16**). Growth of hard coral on this part of the shoal over the Holocene period may account for the geological origin of this relatively shallow feature. Like Goeree Shoal, the surface of Eugene McDermott Shoal appears relatively smooth at a coarse scale (> 500 m) but is much more rugose at finer scales (10 m to 100 m).

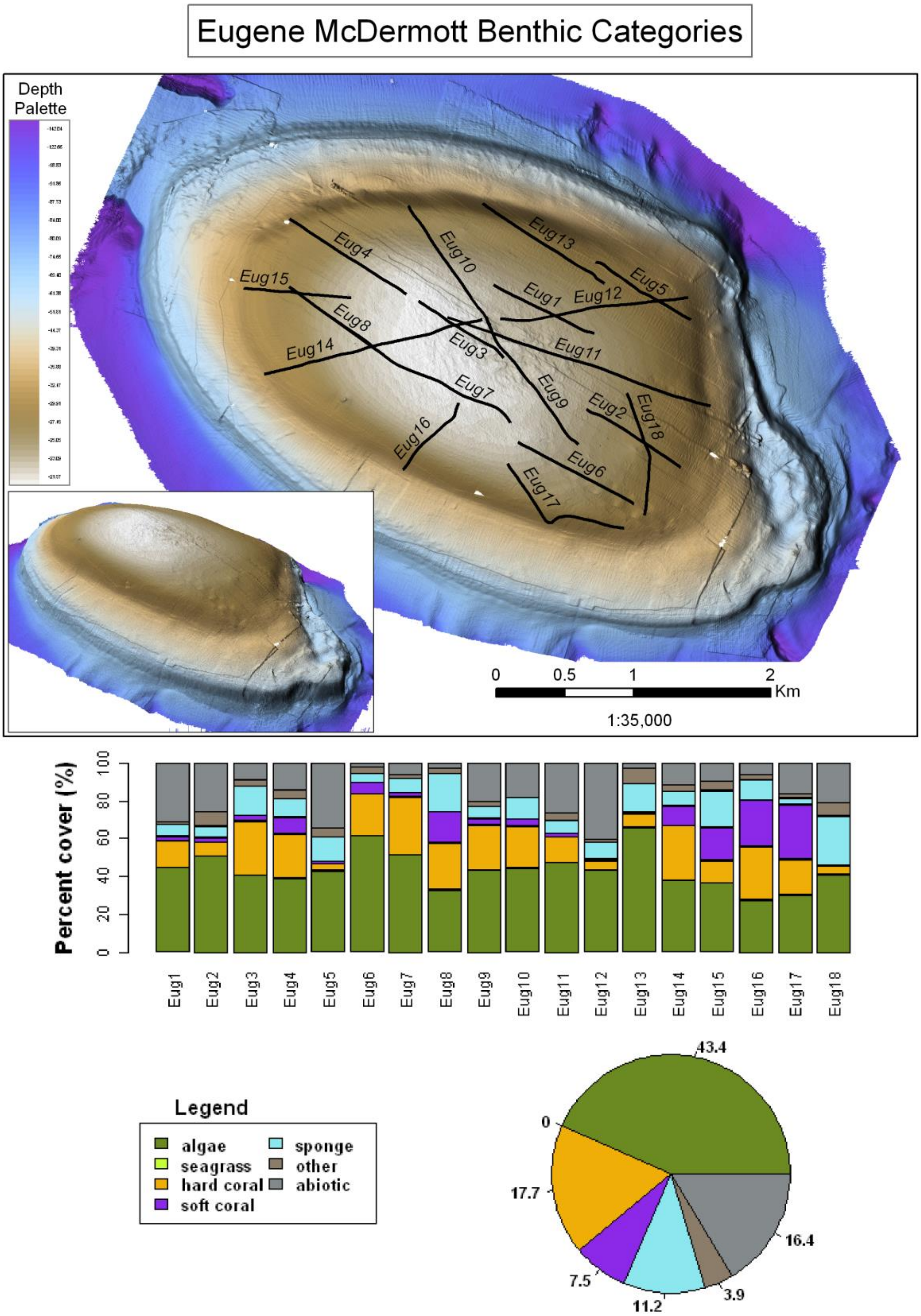



Figure 6-15: Eugene McDermott Shoal Morphology, Depth and Abundance of Major Benthic Groups derived from Multibeam Echo Sounder and Towed Video Surveys (from Heyward et al. 2012)

Eugene McDermott Shoal appears to have formed in a similar manner to other shoals and banks in the region, with the in-situ generation of biogenic sediment thought to account for the growth of the shoal.

Sampling results indicate sediments at Eugene McDermott Shoal have a higher portion of fine sediments than other shoals in the region (Heyward et al. 2017). This may be a consequence of the greater average depth of Eugene McDermott Shoal resulting in lower current velocities on the shoal plateau, with consequently reduced resuspension and transport of fine sediments.

Benthic habitats on the plateau of Eugene McDermott Shoal are characterised by mixed biota and hard corals interspersed with other habitat types (**Figure 6-16**), which is similar to other shoals in the region (Heyward et al. 2012). Habitats in < 30 m of water are characterised by consolidated reef (and associated turfing algae), hard coral, sand and algae (Heyward et al. 2017). The abundance of hard coral habitat at Eugene McDermott Shoal decreases with increasing water depth (Heyward et al. 2017). Modelled substrate types were closely correlated with habitat types (**Figure 6-16**).

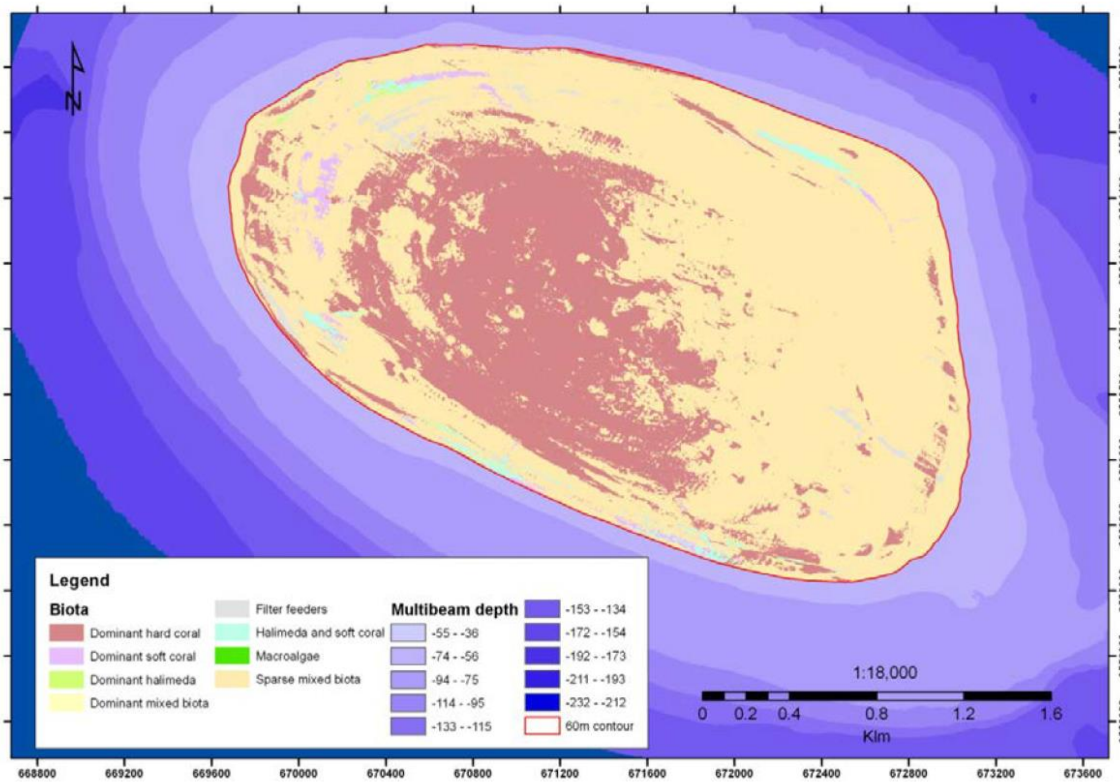



Figure 6-16: Composite Modelled Benthic Habitats of Eugene McDermott Shoal (from Heyward et al. 2012)

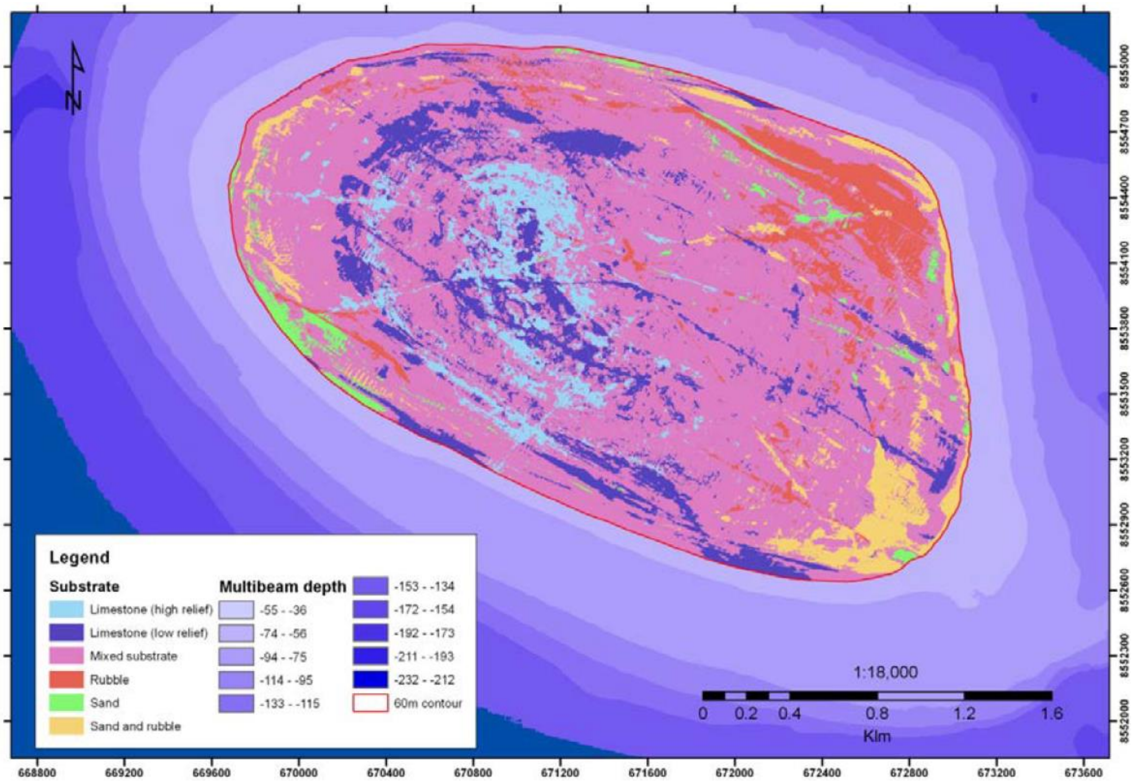



Figure 6-17: Composite Modelled Substrate Types of Eugene McDermott Shoal (from Heyward et al. 2012)

Like other shoals in the region, Eugene McDermott Shoal supports relatively diverse and abundant fish assemblages compared to the surrounding deeper continental shelf habitat. Higher fish assemblage diversity was identified by Heyward et al. (2012) at Eugene McDermott Shoal than the smaller nearby Goeree Shoal, which may be a consequence of the greater variation in benthic habitats. The coral habitat in the shallower part of the shoal hosted species such as grouper (Serranidae), damselfish (Pomacentridae) and wrasses (Labridae), which was similar to the assemblage in this habitat at Goeree Shoal (Heyward et al. 2012). Deeper parts of the shoal plateau with relatively high reef cover hosted angelfish (Pomacanthidae), groupers (Serranidae) and wrasses (Labridae) (Heyward et al. 2012). The relatively deep peripheral shoal hosted a less diverse assemblage hosting wrasses (Labridae), houndsharks (Triakidae) and dartfish (Ptereleotrinae) (Heyward et al. 2012).

**Vulcan Shoal**

Vulcan Shoal is the furthest named shoal from the Crux platform within the Crux in-field development area, lying approximately 22 km north-west of the Crux platform. As with other shoals within the Crux in-field development area, Shell has applied a 1 km buffer around this shoal within which no activities will take place. Vulcan Shoal rises steeply from the surrounding continental shelf, from around 180 m water depth to the plateau of the shoal at approximately 20-40 m water depth (**Figure 6-18**). The plateau of the shoal is relatively large compared to other shoals in the region. Shallower regions around the margin of the plateau host hard coral communities (**Figure 6-19**). As with Goeree Shoal, growth of hard corals may account for the geological origin of these relatively shallow parts of the plateau. The surface of Vulcan Shoal is relatively smooth at coarse scales (> 500 m), but rugose at finer scales (10 m to 100 m), creating complex habitat.

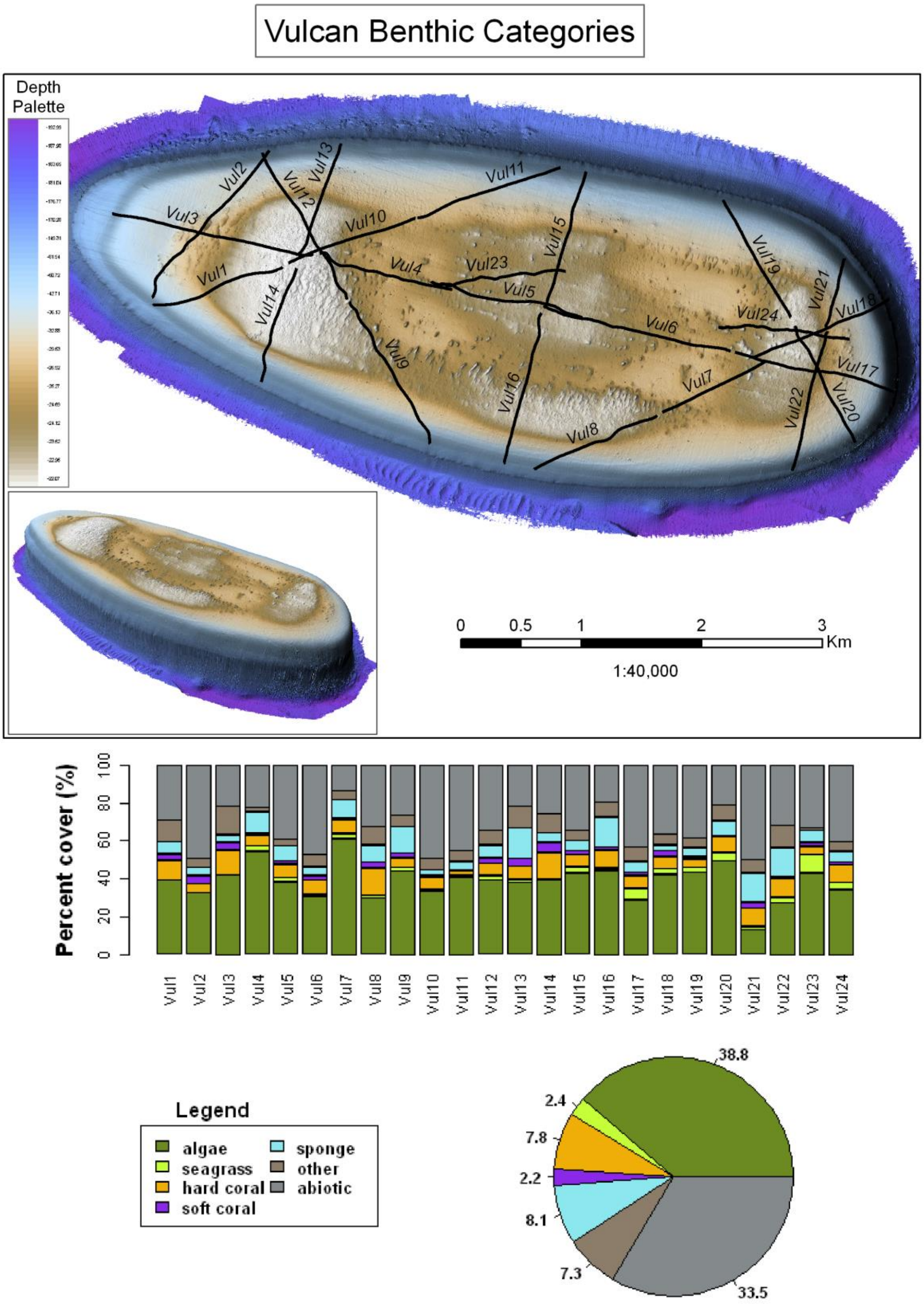



Figure 6-18: Vulcan Shoal Morphology, Depth and Abundance of Major Benthic Groups derived from Multibeam Echo Sounder and Towed Video Surveys (from Heyward et al. 2012)

The geological origin of Vulcan Shoal appears consistent with other shoals in the region, with in situ biogenic sediment production from *Halimeda* spp. and hard corals the likely sediment sources. Sediments from Vulcan Shoal are predominantly (> 80% by mass) sand-sized or smaller (i.e. < 2 mm). The grain size distribution is consistent with shoals of similar depth in the region (Heyward et al. 2017).

Benthic habitats on the plateau of Vulcan Shoal are characterised by mixed biota covering the central part of the shoal, with hard coral habitat concentrated around the margin of the shoal (**Figure 6-19**). Habitats in < 30 m were characterised by sand, algae and unconsolidated reef. Between 30 and 60 m the relative portion of sand increased, while photosynthetic taxa (algae and zooxanthellate corals) decreased. Of interest, seagrass meadows were observed at Vulcan Shoal in 2010 but had significantly declined by 2011 and had not recovered by 2013. Modelled substrate types were closely correlated with habitat types (**Figure 6-20**).

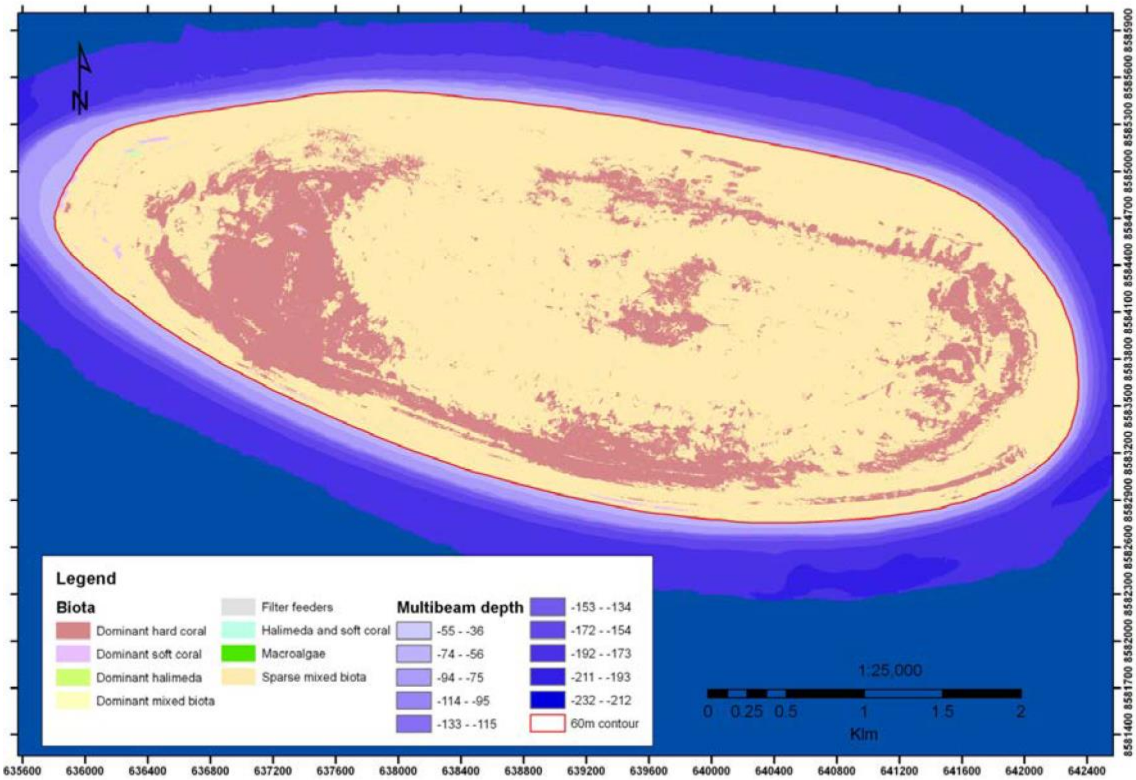



Figure 6-19: Composite Modelled Benthic Habitats of Vulcan Shoal (from Heyward et al. 2012)

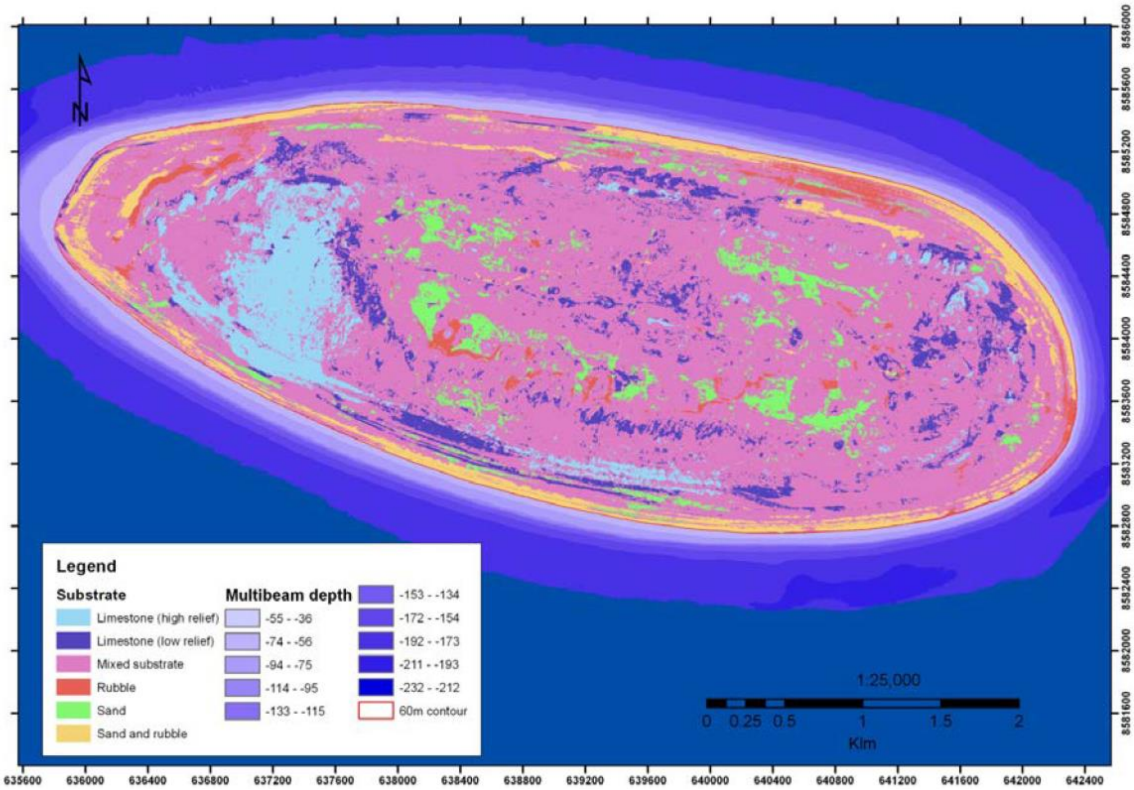



Figure 6-20: Composite Modelled Substrate Types of Vulcan Shoal (from Heyward et al. 2012)

While larger in size, the composition of benthic habitats at Vulcan Shoal was similar to other shoals within the boundary of the Crux in-field development area. The fish assemblage associated with the relatively shallow areas with high coral cover include angelfish (Chaetodontidae), butterfly fish (Pomacanthidae) and snapper (Lutjanidae) (Heyward et al. 2012). Shallower areas with less reef cover supported species that were less likely to be site-attached and included trevally (Carangidae), wrasses (Labridae) and scad (Carangidae) (Heyward et al. 2012). Deeper areas with low reef cover supported wrasses (Labridae), houndsharks (Triakidae) and dartfish (Ptereleotrinae) (Heyward et al. 2012).

## 6.4.5 Offshore Reefs and Islands

There are no known offshore reefs or islands within or in close proximity to the project area. However, there are a number of emergent oceanic reefs and islands offshore of northern Australia. The main offshore reefs and islands in the region include Ashmore Reef, Cartier Island, Hibernia Reef, Browse Island, Seringapatam Reef, Scott Reef and Adele Island (**Figure 6-11**). These reefs/islands occur within the area of influence and are discussed below. The Tiwi Islands, Christmas Island and Cocos (Keeling) Islands are also discussed as they occur within the area of influence; however, they are significantly more distant from the project area.

### 6.4.5.1 Ashmore Reef

Ashmore Reef lies approximately 155 km north-west of the Crux platform and is protected by the Ashmore Reef Marine Park (**Section 6.6.8**). Ashmore Reef is also a designated Ramsar wetland of international significance (**Section 6.6.7**).

Ashmore Reef is a large platform reef complex containing an atoll-like structure with two lagoons, large areas of drying flats that become exposed at low tide, shifting sand banks and three vegetated sandy cays: West Island (281,000 $km^2$), East Island (134,200 $km^2$), and Middle Island (129,800 $km^2$) (ConocoPhillips 2018). The surrounding reef consists of a well-developed reef crest and a broad reef flat that can be up to 3 km across. Water depths in the lagoons vary from extremely shallow waters around the sand banks to up to 45 m deep. The three islands located within the lagoon are mostly flat, being composed of coarse sand with a few areas of exposed beach rock and limestone outcrops (ConocoPhillips 2018; Shell 2009).

#### 6.4.5.2 Cartier Island

Cartier Island lies approximately 105 km north-west of the Crux platform and 45 km from Ashmore Reef. The island and surrounding reefs are protected by Cartier Island Marine Park (**Section 6.6.8**). Cartier Island is an un-vegetated sand cay surrounded by a wide platform, that rises steeply from the seabed, and fringing coral reef flats (ConocoPhillips 2018). The coarse sandy beaches of the island support large populations of nesting green turtles.

#### 6.4.5.3 Hibernia Reef

Hibernia Reef is located approximately 160 km north-west of the Crux platform and is situated approximately 40 km north-east from Ashmore Reef and 60 km north-west of Cartier Island. The reef is less extensive than that at Ashmore Reef and Cartier Island and is roughly oval in shape, tapering to a point on the western side (ConocoPhillips 2018; Shell 2009). The reef complex contains a deep central lagoon and drying sand flats. There is no permanent land at Hibernia Reef, however, large areas of the reef are exposed at low tide.

#### 6.4.5.4 Browse Island

Browse Island lies approximately 158 km south-west of the Crux platform. The island and surrounding waters within a distance of three nautical miles (nm) are WA State Territorial Waters. Browse Island is a sand and limestone cay situated on a limestone and coral reef, covering an area of 13 ha (0.13 km$^2$) (Shell 2009). The reef is a flat topped, oval shaped platform reef with a diameter of 2.2 km at its widest point (INPEX 2010). The reef complex rises from a depth of approximately 200 m. The intertidal habitats around the island include (INPEX 2010):

- sandy beaches or coarse coral sand, which is a known turtle nesting site for green turtles (*Chelonia mydas*)
- beach rock which supports invertebrate fauna
- a lagoon with sand and coral rubble substrates and live corals such as Acropora spp. and *Porites* spp.
- a reef platform, containing areas of sand and coral rubble, limestone supporting sparse algal turf and many barren shallow pools, which is exposed at low tide
- the reef crest, which supports a diverse range of molluscs and hard corals of the Faviidae family (such as *Goniastrea* spp.), and
- a wave swept seaward ramp which supports some algae and coral.

The shallow subtidal zone (< 20 m depth) of Browse Island ranges from 50 to 200 m wide and is comprised mainly of bare limestone, with the most diverse coral communities (including *Hydnophora rigida, Acropora* and to a lesser extent *Porites)* recorded in raised coral reefs in shallower areas around the island (INPEX 2010). The benthic habitats were noted as being characteristic of coral platform reefs throughout the Indo-West Pacific region and limited in their extent in the subtidal region.

### 6.4.5.5 Seringapatam Reef

Seringapatam Reef (approximately 270 km south-west of the Crux platform) is a remote atoll covering an area of approximately 55 $km^2$ and encloses a lagoon of relatively consistent depth of approximately 20 m (maximum depth of 30 m) (ConocoPhillips 2018). The lagoon is connected to the ocean by a narrow passage in the northeast part of the reef.

Seringapatam Reef is recognised as a Key Ecological Feature (KEF) (**Section 6.4.7**). The reef is a regionally important scleractinian coral reef as it has a high biodiversity. Results from the Western Australian Museum (WAM) survey in 2006 noted 159 species of scleractinian corals with a hard coral cover of approximately 16% (WAM 2009). The dominant benthic habitats of the reef have been observed to include turf algae, macroalgae, hard and soft corals, algae and filter feeders (e.g. sponges, gorgonians, hydroid, seapens) (ConocoPhillips 2018).

### 6.4.5.6 Scott Reef

Scott Reef (located approximately 290 km south-west of the Crux platform) is a large oceanic atoll platform which rises vertically from the seafloor in water depths between approximately 400 m and 700 m and comprises two lagoonal areas (North and South Scott Reef). North Scott Reef is approximately 17 km long and 16 km wide (Gilmour et al. 2013, Woodside 2014). South Scott Reef is approximately 20 km wide. Water depths within Scott Reef vary between 0 m and 80 m with areas of the reef flat being exposed at low tide. Sandy Islet, a small sandy cay, is the sole permanently emergent land and is approximately 700 m long and 60 m wide (Woodside 2012). Sandy Islet is a significant nesting site for green turtles, predominantly during the summer months (Gilmour et al. 2013), as well as being a foraging and breeding area for a number of seabird species (Woodside 2012).

Scott Reef is recognised as a KEF (**Section 6.4.7**). Corals communities at Scott Reef occur across shallow (< 30 m) and deep (> 30 m) habitats, with 306 species from 60 genera and 14 families having been identified (Gilmour et al. 2009). Coral communities varied from shallow to deep water with 295 species recorded from shallow water environments and 51 species from deep water. Eleven species were only found in deep water environments. None of the corals recorded were endemic to Scott Reef (Gilmour et al. 2009). Biodiversity at Scott Reef is similar to that of other offshore emergent reefs in the region (e.g. Seringapatam Reef, Ashmore Reef and Rowley Shoals), with the biological assemblages being a sub-set of Indo-Pacific reefs.

### 6.4.5.7 Adele Island

Adele Island is located off the central Kimberley coast and is approximately 314 km south-west of the in-field development area.

The fish-hook shaped island, measuring 2.9 km by 1.6 km with an area of 2.17 $km^2$, and its surrounding extensive sandbanks sit atop a shallow-water limestone platform (Ecosure 2009). The island is surrounded by extensive coral reefs and is an important site for breeding seabirds, with rookeries of the lesser frigate, brown booby, red-footed booby, lesser crested tern and masked booby (Ecosure 2009).

### 6.4.5.8 Tiwi Islands

The Tiwi Islands are comprised of two main islands (Bathurst and Melville Islands) and nine smaller uninhabited islands. The islands are located approximately 80 km north of Darwin and 624 km east of the Crux platform. The Tiwi Islands comprise a total area of approximately 8,320 $km^2$ with a coastline of 1,016 km, and are Aboriginal freehold land owned by the Tiwi Aboriginal Land Trust (Natural Resources, Environment, the Arts and Sport (NRETAS) 2009a).

Due to the isolation of the Tiwi Islands from the Australian mainland, as well as climatic extremes (including high rainfall events), many species found on the islands are not present in the NT (NRETAS 2009a). The diverse array of coastal habitats on the Tiwi Islands includes mangroves, tidal mudflats, sandy beaches, seagrass meadows and fringing reef habitats, as well as eucalypt, paperbark and monsoon vine forests (Tiwi Islands Regional Council 2018). The islands support nesting habitat for marine turtles, internationally significant seabird rookeries, and some major aggregations of migratory shorebirds (NRETAS 2009a). The north coast of the islands is recognised as key areas for the conservation of dugongs and seagrass habitats (Parks and Wildlife Service Northern Territory (PWSNT) 2003).

#### 6.4.5.9 Christmas Island

Christmas Island is located in the Indian Ocean and is approximately 2,061 km west-north-west of the Crux platform. A significant portion (approximately 66%) of the island comprises the Christmas Island National Park, which is managed by Parks Australia. The National Park protects the approximately 80,000 seabirds which nest on the island each year, as well as the abundant and species diverse land crabs, plants and tropical rainforest habitat, and two Ramsar wetlands (see **Section 6.6.7**) (Director of National Parks 2014). More than 100 migrant and vagrant seabird species have been recorded on Christmas Island, including nine resident breeding seabird species and 23 vagrant/nonbreeding seabirds (Director of National Parks 2014). The island supports a large number of endemic species (254 taxa) due to its isolated oceanic location. The marine environment supports fringing coral reefs, terrace and cave systems, and more than 600 species of fish (Director of National Parks 2014). The waters also support threatened green and hawksbill turtles.

#### 6.4.5.10 Cocos (Keeling) Islands

The Cocos Islands, located approximately 2,990 km west of the Crux platform in the Indian Ocean, are an atoll consisting of 27 coral islands. North Keeling Island, the northern atoll island, and surrounding waters form the Pulu Keeling National Park, which is administered by Parks Australia. The North Keeling Island is characterised by a broken, irregular fringing coral reef, with the exception of the north-west corner. The marine component of the National Park comprises three major marine habitat types; the outer reef slope (subtidal), reef flats including sandy and rocky shores (predominantly intertidal) and lagoon (predominantly subtidal). The waters surrounding the island support a diverse array of marine fauna, including dolphins, turtles, fish (approximately 550 species), crustaceans, molluscs and corals (Director of National Parks 2015).

North Keeling Island supports an internationally significant seabird rookery as it provides a focal point for birds within a huge expanse of the central-eastern Indian Ocean (Director of National Parks 2015). Thirteen species of birds in the park are listed under international migratory bird agreements between Australia and Japan, China and the Republic of Korea (JAMBA, CAMBA and ROKAMBA). The island and surrounding atolls also provide habitat for land crabs and flora species (Director of National Parks 2015).

### 6.4.6 WA and NT Mainland Coastline

The WA and NT mainland coastlines are only of relevance in the context of the area of influence as areas of the coastline may be contacted in an unlikely emergency event resulting in a large-scale release of hydrocarbons (see **Section 8.4.9**).

The Crux platform is located 190 km from the nearshore and coastal environments of the Kimberley on the WA coastline. The Kimberley coastline supports a diverse array of marine habitats and communities including coral reefs, sandy beaches, rocky shores, seagrass meadows, mangroves, sponge gardens, wetlands, estuaries, creeks and rivers (Department of Environment and Conservation (DEC) 2009a). These environments in turn support a number of fauna, including EPBC listed seabirds and migratory shorebirds, turtles, sea snakes, dugongs, cetaceans, fish, sharks and rays (DEC 2009a). The values and sensitivities of the Kimberley coastline are considered representative of those for the extended northern WA coastal area.

The NT coastline, located 539 km from the Crux platform, supports a variety of marine habitats including coral reefs, seagrass meadows, mangroves and sand or mudflats (NT Government 2018a). These coastal habitats in turn provide important areas for breeding, nursery and foraging for numerous marine species such as fish, marine turtles, cetaceans, dugongs and sharks (NT Government 2018a).

Threatened marine species that occur within the area of influence where it is predicted to contact the WA/NT mainland coastline are described in **Section 6.5.**

The WA/NT nearshore and coastal areas provide Indigenous and European heritage value, as well as cultural, social and economic values such as local tourism and recreation. The nearshore and coastal habitats also support a number of culturally and commercially significant marine fauna species such as marine turtles, dugongs, fish and prawns (DEC 2009a).

### 6.4.7 Key Ecological Features

KEF are elements of the Commonwealth marine environment that are considered to be of regional importance for either the marine region's biodiversity or its ecosystem function and integrity. KEFs are not listed as MNES and have no legal status in their own right.

A search of the DoEE National Conservation Values Atlas identified a number of KEFs that occur within or adjacent to the project area and area of influence (**Figure 6-21**). A summary of the KEFs is provided in **Table 6-4** (DSEWPaC 2012a, 2012b). Only one KEF is intersected by the Crux project, with the export pipeline intersecting a small portion of the continental slope demersal fish communities.

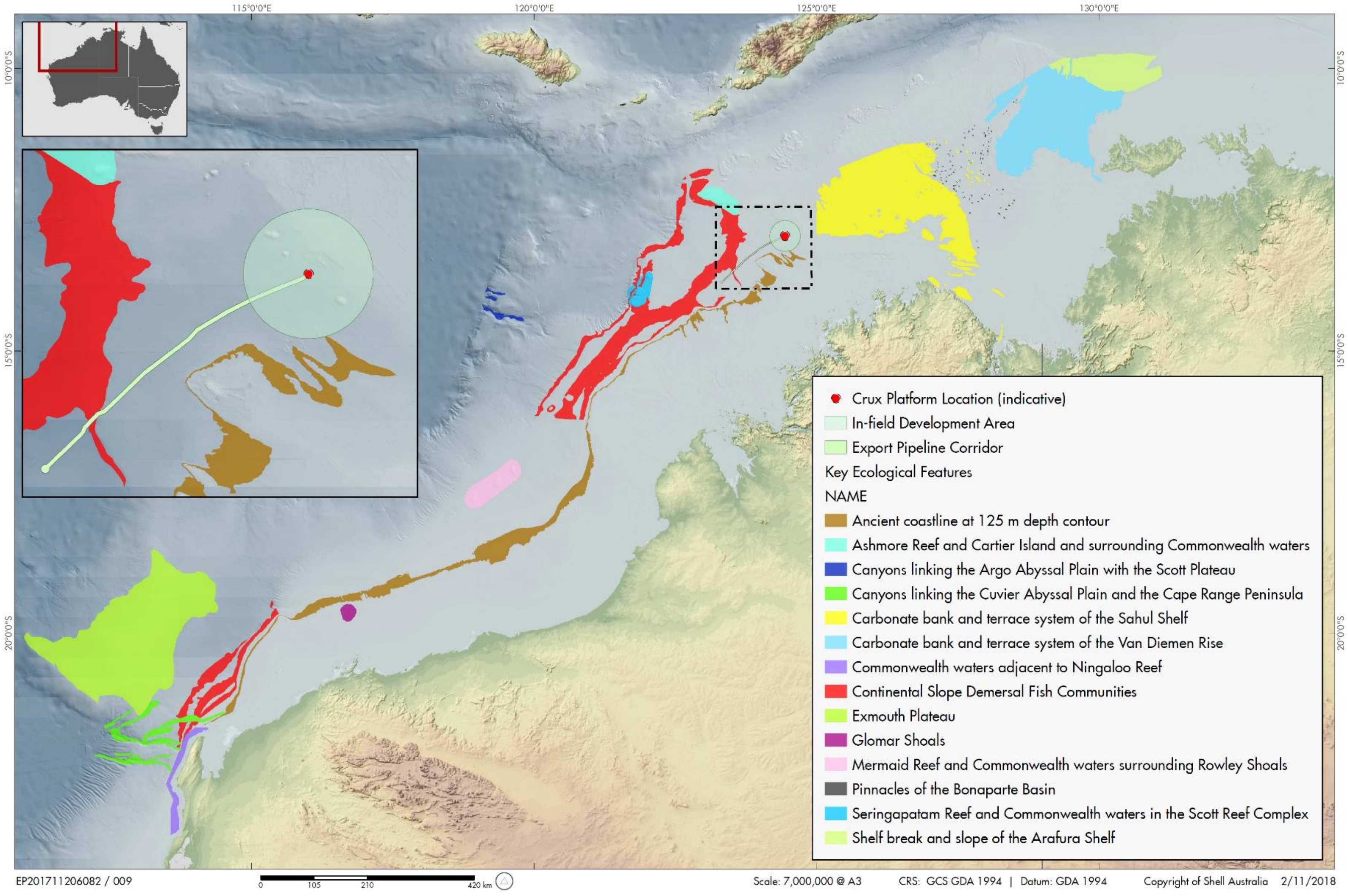



Figure 6-21: Key Ecological Features

Table 6-4: KEFs Relevant to the Project

| KEF | Relevance to Crux Project | Summary of Key Values |
|---|---|---|
| Ancient coastline at 125 m depth contour | Located 30 km south of the Crux platform and is therefore directly adjacent to the in-field development area | *Unique seafloor feature with ecological properties of regional significance*<br>The areas of hard substrate along this ancient coastline, which follows the 125 m depth contour, are thought to provide biologically important habitats in areas otherwise dominated by soft sediments; thereby providing for higher species diversity and richness relative to the wider region. The topographic complexity of these escarpments may also facilitate vertical mixing of the water column providing a relatively nutrient-rich environment for species present on the escarpment. The KEF encompasses an area of approximately 16,190 km$^2$. |
| Ashmore Reef and Cartier Islands and surrounding Commonwealth waters | Located 100 km north-west of the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>Ashmore Reef is the largest of only three emergent oceanic reefs present within the north-eastern Indian Ocean and is the only oceanic reef in the region with vegetated islands. The emergent reefs are known to provide areas of enhanced primary productivity in otherwise oligotrophic environments.<br>Ashmore Reef and Cartier Islands and the surrounding Commonwealth waters are regionally important for feeding and breeding aggregations of seabirds and shorebirds, and other marine life. Ashmore Reef regularly supports more than 40,000 waterbirds (those ecologically dependant on wetlands) and is estimated to support as many as 100,000 seabirds in a twelve month period (Hale 2013).<br>The marine habitats supported by the reefs are nationally and internationally significant, providing habitat for diverse and abundant marine reptile (including feeding, nesting and internesting areas for green, hawksbill and loggerhead turtles) and marine mammal populations, including dugongs.<br>Species at Ashmore and Cartier include more than 225 reef-building corals, 433 molluscs, 286 crustaceans, 192 echinoderms, and 709 species of fish. Thirteen species of sea snakes occur in high numbers at Ashmore and Cartier reefs but are in decline.<br>Additionally, Ashmore Reef supports the highest number of coral species of any reef off the WA coast and plays a primary role in the maintenance of the biodiversity of reef systems in the region. |
| Canyons linking the Argo Abyssal Plain with Scott Plateau | Located 525 km south-west of the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>Canyons linking the Argo Abyssal Plain with Scott Plateau covers an area of approximately 836 km$^2$. The Bowers and Oats canyons are major canyons on the slope between the Argo Abyssal Plain and Scott Plateau and deeply cut into the Scott Plateau at depths of approximately 2,000 m – 3,000 m. The ocean area above the canyons is thought to be an area of moderately enhanced productivity, attracting aggregations of fish, sharks, toothed whales and dolphins. |
| Carbonate bank and terrace system of the Sahul Shelf | Located 60 km north-east of the Crux platform and occurs within the area of influence | *Unique seafloor feature with ecological properties of regional significance*<br>While little is known about this KEF, the carbonate banks and terrace system of the Sahul Shelf is considered regionally important because of their role in enhancing biodiversity and local productivity relative to their surrounds, largely due to the presence of elevated hard substrates. The seabed features are thought to create enhanced productivity and biodiversity as a result of upwellings of cold nutrient-rich water at the heads of the channels. |

| KEF | Relevance to Crux Project | Summary of Key Values |
|---|---|---|
| | | The KEF covers an area of approximately 41,158 km$^2$. The banks rise to depths of 150 m – 300 m and are separated from each other by narrow meandering channels which are up to 150 m deep. The hard substrates of the banks are thought to support a high diversity of organisms including reef-fish, sponges, soft and hard corals, gorgonians, bryozoans, ascidians and other sessile filter feeders. |
| Continental slope demersal fish communities | Located 73 km south-west of the Crux platform, is intersected by a small portion of the Crux export pipeline corridor (0.04%) and occurs within the area of influence | *Communities with high species biodiversity and endemism*<br>There is a high diversity of demersal fish assemblages on the Australian continental slope from the North West Cape to the edge of the NMR. Specifically, 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 the whole of Australia (DEHWA 2008). The Timor Province and Northwest Transition bioregions, in which the Crux project is located, are the second-richest areas for demersal fish across the entire continental slope.<br>The KEF covers a vast area of approximately 33,182 km$^2$. |
| Glomar Shoals | Located 1,090 km south-west of the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>The Glomar Shoals (approximately 786 km2) are a submerged littoral feature located approximately 150 km north of Dampier on the Rowley shelf at depths of 33 m – 77 m. While biological data is limited, the fish of Glomar Shoals are believed to be a subset of reef-dependent species. The shoals are known to be an important area for a number of commercial and recreational fish species such as rankin cod, brown-striped snapper, red emperor, crimson snapper, bream and yellow-spotted triggerfish. |
| Mermaid Reef and Commonwealth waters surrounding Rowley Shoals | Located 674 km south-west of the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>The Rowley Shoals consist of three atoll reefs; Clerke, Imperieuse and Mermaid Reef which support 214 coral species and around 530 species of fish. The steep changes in slope around the reef also attract a range of migratory pelagic species such as dolphins, tuna, billfish and sharks. The coral communities of Mermaid Reef are also an important feature.<br>The enhanced productivity at the shoals is thought to be facilitated by the breaking of internal waves in the waters surrounding the reefs, causing mixing and re-suspension of nutrients from water depths of 500–700 m into the photic zone. |
| Pinnacles of the Bonaparte Basin | Located 310 km from the Crux platform and occurs within the area of influence | *Unique seafloor feature with ecological properties of regional significance*<br>The limestone pinnacles in the western Bonaparte Depression are expected to support a diverse community in an otherwise oligotrophic system. More than 110 pinnacles occur in the Bonaparte Depression, covering a total area of more than 520 km$^2$. The pinnacles are thought to be the eroded remnants of underlying strata and can be up to 50 m high and 50 km–100 km long. |

| KEF | Relevance to Crux Project | Summary of Key Values |
|---|---|---|
| Seringapatam Reef and Commonwealth waters in the Scott Reef complex | Located 265 km from the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>The coral communities at Seringapatam and Scott Reefs play a key role in maintaining species richness and aggregations of marine life. The reefs and the waters surrounding them attract aggregations of marine life including humpback whales on their northerly migration, Bryde's whales, pygmy blue whales, Antarctic minke whales, dwarf minke whales, minke whales, dwarf sperm whales, spinner dolphins and whale sharks. Green and hawksbill turtles nest during the summer months on Sandy Islet on South Scott Reef. These species also internest and forage in the surrounding waters.<br>Scott Reef is a particularly biologically diverse system and includes more than 300 species of reef-building corals, approximately 400 mollusc species, 118 crustacean species, 117 echinoderm species, around 720 fish species and several species of sea snakes. |
| Exmouth Plateau | Located 1,276 km from the Crux platform and occurs within the area of influence | *Unique seafloor feature with ecological properties of regional significance*<br>Due to its large size (approximately 49,310 km$^2$), the plateau is thought to modify deepwater flow and be associated with the generation of internal tides in the Exmouth region. These oceanic processes may contribute to the upwelling of nutrients, which result in areas of increased productivity.<br>The plateau ranges in depth between 800 m to 4,000 m and features valleys and channels that support a range of benthic environments. These features are also thought to provide conduits for the transport of sediment and other materials from the plateau surface to deeper areas.<br>While the Exmouth Plateau has low habitat heterogeneity, it is likely to be an important area of biodiversity as it provides an extended area for communities adapted to depths of around 1,000 m. |
| Shelf break and slope of the Arafura Shelf | Located 626 km from the Crux platform and occurs within the area of influence | *Unique seafloor feature with ecological properties of regional significance*<br>The shelf break and slope of the Arafura Shelf is described as a biogeographic crossroad of biota from the Timor-Indonesian-Malay region. Whilst there is limited information about the ecosystem processes of the area, it is thought that the ITF current and surface wind-driven circulation from the north-west monsoon are a strong influence. These oceanic processes are likely to drive pelagic dispersal of nutrients, species and biological productivity and, in turn, the long term patterns in transport and dispersal of larvae juvenile and migrating adult organisms through the area. Demersal fish communities are diverse and the area is likely to support whale sharks, sharks and marine turtles. |
| Carbonate bank and terrace system of the Van Diemen Rise | Located 430 km from the Crux platform and occurs within the area of influence | *Unique seafloor feature with ecological properties of regional significance*<br>The bank and terrace system of the Van Diemen Rise covers approximately 31,278 km$^2$ and forms part of the larger system associated with the Sahul Banks to the north and Londonderry Rise to the east. The complex topographic features of the area consist largely of raised geomorphic features (e.g. terraces and banks) with relatively high proportions of hard substrate, supporting sponge and octocoral gardens. These sponge and coral communities in turn provide habitat for epifauna. Infauna, including polychaetes and ascidians, are also scattered throughout the KEF.<br>Variability in water depth and substrate composition is thought to contribute to the richness in benthic epifauna and the unique ecosystems found in the area. The carbonate banks |

| KEF | Relevance to Crux Project | Summary of Key Values |
|---|---|---|
| | | and shoals found within the Van Diemen Rise make up 80% of the banks and shoals, 79% of the channels and valleys, and 63% of the terrace found across the NMR. The carbonate banks and shoals rise from depths of 100 m–200 m to within 10 m–40 m of the sea surface (Anderson et al. 2011). |
| Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula | Located 1,404 km from the Crux platform and occurs within the area of influence | *Unique seafloor features with ecological properties of regional significance*<br>The nutrient-rich and high productivity waters of the KEF are associated with aggregations of whale sharks, manta rays and sharks, humpback whales, sea snakes, sharks, large predatory fish and seabirds. The canyons are thought to connect to the Commonwealth waters adjacent to Ningaloo Reef, as well as the Exmouth Plateau.<br>The KEF also supports unique seafloor features of a regional significance with regards to both benthic and pelagic ecological habitats. |
| Commonwealth waters adjacent to Ningaloo Reef | Located 1,451 km from the Crux platform and occurs within the area of influence | *High productivity and aggregations of marine life*<br>Ningaloo Reef is of global significance as it is the only coral reef in the world that fringes the west coast of a continent and is a seasonal aggregation site for the whale shark.<br>The high degree of interconnectivity with regional canyons and plateau contributes to high levels of productivity and species richness of the Ningaloo Reef. The reef supports aggregations and migration pathways of whale sharks, manta rays, humpback whales, sea snakes, sharks, large predatory fish and seabirds. The deepwater biodiversity includes unique assemblages of sponge and filter-feeder communities (compared with the Dampier Archipelago and Abrolhos Islands) which are indicative of areas of potentially high and unique sponge biodiversity. |

#### 6.4.7.1 Anthropogenic Pressures

The DoEE Commonwealth Marine Report Cards for the North and North-west Marine Regions (DSEWPaC 2012a, 2012b) provide a high-level analysis of the anthropogenic pressures on the KEFs. The analysis defines five categories in which each pressure impacts on the designated KEF including ‘of concern’, ‘of potential concern’, ‘of less concern’, ‘not of concern’ and ‘data deficient or not assessed’. For the purposes of this OPP only pressures applicable to the project activities outlined in **Section 5** have been considered. A summary of the pressure analysis is detailed in **Table 6-5**, with further description provided below for the pressures ‘of potential concern’ and where there is a credible risk of interaction with project activities.

Table 6-5: KEFs Anthropogenic Pressure Analysis

| Pressure | Physical Habitat Modification | Invasive Species | Noise Pollution | | Light Pollution[1] | Marine Debris | Oil Pollution | |
|---|---|---|---|---|---|---|---|---|
| | Offshore Construction | Vessels | Vessels | Offshore Construction | Vessels and Oil and Gas Infrastructure | Vessels | Oil Rigs | Shipping |
| Ancient coastline at 125 m depth contour | | | | | | | | |
| Ashmore Reef and Cartier Islands and surrounding Commonwealth waters | | | | | | | | |
| Canyons linking the Argo Abyssal Plain with Scott Plateau | | | | | | | | |
| Carbonate bank and terrace system of the Sahul Shelf | | | | | | | | |
| Continental slope demersal fish communities | | | | | | | | |
| Glomar Shoals | | | | | | | | |
| Mermaid Reef and Commonwealth waters surrounding Rowley Shoals | | | | | | | | |
| Pinnacles of the Bonaparte Basin | | | | | | | | |
| Seringapatam Reef and Commonwealth waters in the Scott Reef complex | | | | | | | | |
| Exmouth Plateau | | | | | | | | |
| Shelf break and slope of the Arafura Shelf | | | | | | | | |
| Carbonate bank and terrace system of the Van Diemen Rise | | | | | | | | |
| Canyons linking the Cuvier Abyssal Plain | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| and the Cape Range Peninsula | | | | | | | | |
| Commonwealth waters adjacent to Ningaloo Reef | | | | | | | | |

| Key | |
|---|---|
| | Of concern |
| | Of potential concern |
| | Of less concern |
| | Not of concern |
| | Data deficient or not assessed |

[1] The pressure analysis for light pollution was sourced from marine bioregional plans (DSEWPaC 2012a, 2012b) as it was not detailed in the Commonwealth Marine Report Cards.

### 6.4.7.2 Marine Debris

The KEFs of Ashmore Reef and Cartier islands and surrounding Commonwealth waters and Seringapatam Reef and Commonwealth waters in the Scott Reef complex are of potential concern from marine debris. While there is limited region-specific information available on marine debris, key contributing factors for the introduction and spread of debris in the region are present. These include high levels of commercial shipping, increasing use of recreational vessels, active fisheries (recreational and commercial), and significant coastal urban and industrial development (DSEWPaC 2012a). Threats to the marine fauna aggregations associated with the KEFs include the ingestion or entanglement of marine biota which aggregate within these areas (DSEWPaC 2012a).

Marine debris and dropped objects resulting from project related activities are unlikely to materially affect these KEFs given they are located > 100 km from the Crux platform.

### 6.4.7.3 Oil Pollution

Oil pollution resulting from oil rigs is of potential concern to Ashmore Reef and Cartier Islands and surrounding Commonwealth waters, Mermaid Reef and Commonwealth waters surrounding Rowley Shoals, Seringapatam Reef and Commonwealth waters in the Scott Reef complex, and Commonwealth waters adjacent to Ningaloo Reef. Petroleum exploration, development and production in the North and North-west marine region is increasing and shipping is also likely to continue to expand in the region in relation to increasing resource development (DSEWPaC 2012a).

A detailed assessment of the potential impact to these KEFs from oil pollution is provided in **Section 8.4.9**.

## 6.5 Threatened Species and Ecological Communities

### 6.5.1 EPBC Listed Threatened and Migratory Species

An online EPBC Protected Matters Database Search was conducted for the in-field development area, export pipeline corridor and area of influence (**Table 6-6**; DoEE 2018a). A summary of the results is presented below:

- in-field development area – the search identified 20 listed threatened fauna species and 33 listed migratory species (17 of which are also listed as threatened) that may occur or have habitat in the area (DoEE 2018b),
- export pipeline corridor – the search identified 20 listed threatened fauna species and 33 listed migratory species (17 of which are also listed as threatened) that may occur or have habitat in the area (DoEE 2018c). All listed threatened and migratory species in the in-field development area were also identified as occurring in the export pipeline corridor, and
- Area of influence – the search identified 41 listed threatened fauna species and 89 listed migratory species (27 of which are also listed as threatened) that may occur or have habitat in the area (DoEE 2018d).

Forty-three species were excluded from **Table 6-6** as they are not considered relevant to the project, given they are commonly associated with terrestrial habitats that are generally not present on shorelines (e.g. wetlands, forests).

The EPBC Protected Matters results also lists a number of marine and other cetacean species, which are not listed as MNES under the EPBC Act. Refer to **Appendix J** for further details. With regards to marine mammals, a sub-set of these species, and an additional cetacean species (pantropical spotted dolphin; *Stenella attenuata*), have been observed in the NWMR region through surveys and opportunistic observations (pers. comm. R. Clarke, Monash University, 2018). An additional four marine bird species are also known to breed at Ashmore Reef; the eastern great egret (*Ardea modesta*), little egret (*Egretta garzetta*), eastern reef egret (*Egretta sacra*) and nankeen night-heron (*Nycticorax caledonicus*) (Clarke et al. 2011).

A further seven listed migratory species have been noted as potentially transiting the Barossa project area (approximately 713 km north-east of the Crux platform) on an annual basis as part of their migration, and therefore may also transit the project area; wedge-tailed shearwater (*Ardenna pacifica*), Bulwer's petrel (*Bulweria bulwerii*), Matsudaira's storm-petrel (*Hydrobates matsudairae*), Swinhoe's storm-petrel (*Hydrobates monorhis*), Wilson's storm-petrel (*Oceanites oceanicus*), red-tailed tropicbird (*Phaethon rubricauda*), white-winged black tern (*Chlidonias leucopterus*), bridled tern (*Onychoprion anaethetus*) and common tern (*Sterna hirundo*) (ConocoPhillips 2018).

Table 6-6: EPBC Listed Threatened and Migratory Species of Potentially Occurring in the Project Area or Area of Influence

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| *Marine Mammals* | | | | | |
| Sei whale (*Balaenoptera borealis*) | Vulnerable | X | X | X | X |
| Blue whale (*Balaenoptera musculus*) | Endangered | X | X | X | X |

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| Fin whale (*Balaenoptera physalus*) | Vulnerable | X | X | X | X |
| Southern right whale (*Eubalaena australis*) | Endangered | X | | | X |
| Humpback whale (*Megaptera novaeangliae*) | Vulnerable | X | X | X | X |
| Antarctic minke whale (*Balaenoptera bonaerensis*) | | X | | | X |
| Bryde's whale (*Balaenoptera edeni*) | | X | X | X | X |
| Killer whale (*Orcinus orca*) | | X | X | X | X |
| Sperm whale (*Physeter macrocephalus*) | | X | X | X | X |
| Spotted bottlenose dolphin (*Tursiops aduncus*) | | X | X | X | X |
| Dugong (*Dugong dugon*) | | X | | | X |
| Australian snubfin dolphin (*Orcaella heinsohni*) (formally known as the Irrawaddy dolphin) | | X | | | X |
| Indo-pacfic humpback dolphin (*Sousa chinensis*) | | X | | | X |
| *Marine Reptiles* | | | | | |
| Loggerhead turtle (*Caretta caretta*) | Endangered | X | X | X | X |
| Green turtle (*Chelonia mydas*) | Vulnerable | X | X | X | X |
| Leatherback turtle (*Dermochelys coriacea*) | Endangered | X | X | X | X |
| Hawksbill turtle (*Eretmochelys imbricata*) | Vulnerable | X | X | X | X |
| Olive ridley turtle (*Lepidochelys olivacea*) | Endangered | X | X | X | X |
| Flatback turtle (*Natator depressus*) | Vulnerable | X | X | X | X |
| Short-nosed sea snake (*Aipysurus apraefrontalis*) | Critically Endangered | | | | X |
| Leaf-scaled sea snake (*Aipysurus foliosquama*) | Critically Endangered | | | | X |
| *Birds* | | | | | |

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| Australian lesser noddy (*Anous tenuirostris melanops*) | Vulnerable | | X | X | X |
| Red knot (*Calidris canutus*) | Endangered | X | X | X | X |
| Curlew sandpiper (*Caladris ferruginea*) | Critically Endangered | X | X | X | X |
| Great knot (*Calidris tenuirostris*) | Critically Endangered | X | | | X |
| Greater sand plover (*Charadrius leschenaultii*) | Vulnerable | X | | | X |
| Lesser sand plover (*Charadrius mongolus*) | Endangered | X | | | X |
| Christmas Island frigatebird (*Fregata andrewsi*) | Endangered | X | | | X |
| Western Alaskan Bar-tailed Godwit (*Limosa lapponica baueri*) | Vulnerable | | | | X |
| Northern siberian bar-tailed godwit (*Limosa lapponica menzbieri*) | Critically Endangered | | | | X |
| Southern giant-petrel (*Macronectes giganteus*) | Endangered | X | | | X |
| Eastern curlew (*Numenius madagascariensis*) | Critically Endangered | X | X | X | X |
| Abbott's booby (*Papasula abbotti*) | Endangered | | X | X | X |
| Christmas Island white-tailed tropicbird (*Phaethon lepturus fulvus*) | Endangered | | | | X |
| Round Island petrel (*Pterodroma arminjoniana*) | Critically Endangered | | | | X |
| Soft-plumaged petrel (*Pterodroma mollis*) | Vulnerable | | | | X |
| Australian fairy tern (*Sternula nereis nereis*) | Vulnerable | | | | X |
| Tasmanian shy albatross (*Thalassarche cauta cauta*) | Vulnerable | X | | | X |
| White capped albatross (*Thalassarche cauta steadi*) | Vulnerable | X | | | X |
| Campbell albatross (*Thalassarche impavida*) | Vulnerable | X | | | X |

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| Black-browed albatross (*Thalassarche melanophris*) | Vulnerable | X | | | X |
| Common noddy (*Anous stolidus*) | | X | X | X | X |
| Fork-tailed swift (*Apus pacificus*) | | X | | | X |
| Flesh-footed shearwater (*Ardenna carneipes*) | | X | | | X |
| Wedge-tailed shearwater (*Ardenna pacifica*) | | X | | | X |
| Streaked shearwater (*Calonectris leucomelas*) | | X | | | X |
| Lesser frigatebird (*Fregata ariel*) | | X | X | X | X |
| Greater frigatebrd (*Fregata minor*) | | X | X | X | X |
| Caspian tern (*Hydroprogne caspia*) | | X | | | X |
| Bridled tern (*Onychoprion anaethetus*) | | X | | | X |
| White-tailed tropicbird (*Phaethon lepturus*) | | X | | | X |
| Red-tailed tropicbird (*Phaethon rubricauda*) | | X | | | X |
| Roseate tern (*Sterna dougallii*) | | X | | | X |
| Little tern (*Sterna albifrons*) | | X | | | X |
| Masked booby (*Sula dactylatra*) | | X | | | X |
| Brown booby (*Sula leucogaster*) | | X | | | X |
| Red-footed booby (*Sula sula*) | | X | | | X |
| Oriental reed-warbler (*Acrocephalus orientalis*) | | X | | | X |
| Common sandpiper (*Actitis hypoleucos*) | | X | X | X | X |
| Ruddy turnstone (*Arenaria interpres*) | | X | | | X |
| Sharp-tailed sandpiper (*Calidris acuminata*) | | X | X | X | |
| Sanderling (*Calidris alba*) | | X | | | X |

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| Pectoral sandpiper (*Calidris melanotos*) | | X | X | X | |
| Red-necked stint (*Calidris ruficollis*) | | X | | | X |
| Long-toed stint (*Calidris subminuta*) | | X | | | X |
| Little ringed plover (*Charadrius dubius*) | | X | | | X |
| Oriental plover (*Charadrius veredus*) | | X | | | X |
| Swinhoe's snipe (*Gallinago megala*) | | X | | | X |
| Pin-tailed snipe (*Gallinago stenura*) | | X | | | X |
| Oriental Pratincole (*Glareola maldivarum*) | | X | | | X |
| Broad-billed sandpiper (*Limocola falcinellus*) | | X | | | X |
| Asian dowitcher (*Limnodromus semipalmatus*) | | X | | | X |
| Bar-tailed godwit (*Limosa lapponica*) | | X | | | X |
| Black-tailed godwit (*Limosa limosa*) | | X | | | X |
| Little curlew (*Numenius minutus*) | | X | | | X |
| Whimbrel (*Numenius phaeopus*) | | X | | | x |
| Osprey (*Pandion haliaetus*) | | X | | | X |
| Pacific Golden Plover (*Pluvialis fulva*) | | X | | | X |
| Grey plover (*Pluvialis squatarola*) | | X | | | X |
| Crested tern (*Thalasseus bergii*) | | X | | | X |
| Grey-tailed tattler (*Tringa brevipes*) | | X | | | X |
| Wood sandpiper (*Tringa glareola*) | | X | | | X |
| Wandering tattler (*Tringa incana*) | | X | | | X |
| Common greenshank (*Tringa nebularia*) | | X | | | X |

| Species | Threatened Status | Listed as Migratory | Search Area | | |
|---|---|---|---|---|---|
| | | | In-field Development Area | Export Pipeline Corridor | Area of Influence |
| Marsh sandpiper (*Tringa stagnatilis*) | | X | | | X |
| Common redshank (*Tringa totanus*) | | X | | | X |
| Terek sandpiper (*Xenus cinereus*) | | X | | | X |
| *Sharks and Rays* | | | | | |
| Grey nurse shark (*Charcharius taurus*) | Vulnerable | | | | X |
| Great white shark (*Carcharodon carcharias*) | Vulnerable | X | X | X | X |
| Northern river shark (*Glyphis garricki*) | Endangered | | X | X | X |
| Speartooth shark (*Glyphis glyphis*) | Critically Endangered | | | | X |
| Dwarf sawfish (*Pristis clavata*) | Vulnerable | X | | | X |
| Largetooth sawfish (*Pristis pristis*) | Vulnerable | X | X | X | X |
| Green sawfish (*Pristis zijsron*) | Vulnerable | X | X | X | X |
| Whale shark (*Rhincodon typus*) | Vulnerable | X | X | X | X |
| Shortfin mako (*Isurus oxyrinchus*) | | X | X | X | X |
| Longfin mako (*Isurus paucus*) | | X | X | X | X |
| Reef manta ray (*Manta alfredi*) | | X | X | X | X |
| Giant manta ray (*Manta birostris*) | | X | X | X | X |
| Narrow sawfish (*Anoxypristis cuspidata*) | | X | X | X | X |
| Mackeral shark (*Lamna nasus*) | | X | | | X |

### 6.5.2 EPBC Listed Threatened Communities

The EPBC Protected Matters Database does not list any Threatened Ecological Communities (TECs) occurring in the marine environment within the project area (DoEE 2018b). However, one TEC occurs within the area of influence; Monsoon vine thickets on the coastal sand dunes of the Dampier Peninsula (DoEE 2018d). While identified as occurring within the area of influence, the risk of significant impacts to this TEC is not considered credible as, while predominantly restricted to coastlines, this community occurs on the coastal sand dunes (typically the leeward side) (DSEWPaC 2013b) that do not directly contact the marine environment.

### 6.5.3 Biologically Important Areas

BIAs are defined by DoEE as *"spatially defined areas where aggregations of individuals of a regionally significant species are known to display biologically important behaviours such as breeding, foraging, resting or migration"* (DoEE 2018e). BIAs provide a tool for defining areas of importance for marine fauna species.

A review of the DoEE National Conservation Values Atlas (an interactive web-based tool which supports the implementation of Marine Bioregional Plans) (DoEE 2018f) determined that the in-field development area is located within a biologically important area for whale sharks. The whale shark is listed as vulnerable under the EPBC Act and is discussed in detail in **Section 6.5.6**. No other BIAs are intersected or overlapped by the project area.

The area of influence includes a number of BIAs including migration corridors for pygmy blue whales and humpback whales; breeding, calving and foraging areas for the three nearshore dolphin species; nursing/foraging areas for dugongs; foraging and nesting/internesting areas for marine turtles; breeding/foraging/resting areas for a number of seabird species; a migration corridor for whale sharks; and foraging and nursing/pupping areas for three sawfish species. These BIAs are discussed under the relevant species-specific sections in **Section 6.5.6**.

### 6.5.4 Habitat Critical to the Survival of a Species

The EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DoE 2013a) define 'habitat critical to the survival of a species' as areas necessary:

- *"for activities such as foraging, breeding or dispersal*
- *for the long-term maintenance of the species (including the maintenance of species essential to the survival of the species)*
- *to maintain genetic diversity and long term evolutionary development, or*
- *for the reintroduction of populations or recovery of the species."*

Such habitat may be, but is not limited to, habitat identified in a recovery plan and/or habitat listed on the Register of Critical Habitat.

The Crux project does not overlap any habitat critical to the survival of a species. Within the area of influence Ashmore Reef, Cartier Island and Browse Island provide nesting habitat critical to the green turtle. Other mainland and island coastlines with the area of influence also provide habitat critical to the flatback turtle, green turtle, leatherback turtle, loggerhead turtle, and olive ridley turtle. Further discussion of habitat critical to the survival of marine turtles is provided in **Section 6.5.6.2**.

### 6.5.5 Key Biodiversity Areas

Key Biodiversity Areas (KBAs) are sites that contribute significantly to the global persistence of biodiversity (International Union for Conservation of Nature (IUCN) 2016). For a site to qualify as a global KBA it must meet one or more of 11 criteria, grouped into five categories that can be applied to species and ecosystems: threatened biodiversity; geographically restricted biodiversity; ecological integrity; biological processes; and, irreplaceability. Although KBA sites are unrelated to legal status, they are designed to assist Governments around the world to meet their obligations to international treaties.

A review of the World Database of KBAs (Birdlife International 2018) determined that the project area does not fall within any KBAs. The nearest relevant KBAs are Ashmore Reef (as the nearest offshore KBA), Adele Island and Prince Regent and Mitchell River (as the nearest mainland KBA) (Birdlife International 2018; **Figure 6-22**). There are several KBAs in the broader region, with most qualifying as KBAs based on the threatened bird species and populations occurring there. Relevant threatened bird species occurring within the area of influence are discussed in **Section 6.5.6.3**.

For the purpose of this OPP, with a key objective to consider alignment with DoEE published listings for threatened species/communities, BIAs and habitat critical to the survival of a species (as summarised in the previous **Sections 6.5.1 to 6.5.4** inclusive), this international KBA dataset is noted for completeness.

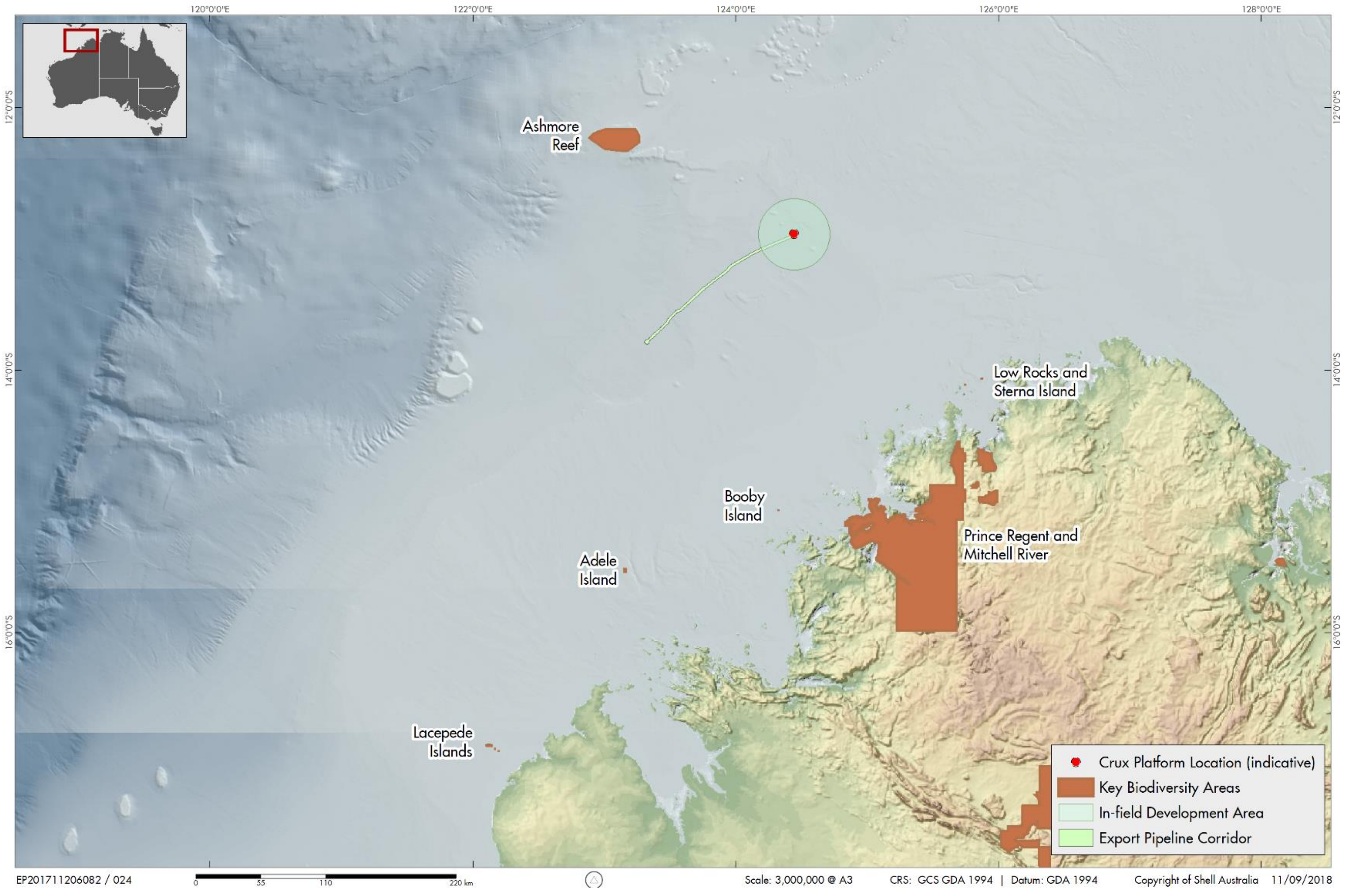



Figure 6-22: Key Biodiversity Areas in Nearest Proximity to the Project Area

### 6.5.6 Key Fauna Species of Relevance to the Crux Project

#### 6.5.6.1 Marine Mammals

Marine mammals are generally widely distributed and highly mobile. In general, distribution patterns reflect seasonal feeding areas, characterised by high productivity, and migration routes associated with reproductive patterns.

Eight migratory species listed under the EPBC Act, including baleen whales, toothed whales and dolphins, were identified as potentially occurring or having habitat within the project area. This includes four threatened species; the blue whale (*Balaenoptera musculus*; endangered), humpback whale (*Megaptera novaeangliae*; vulnerable), sei whale (*Balaenoptera borealis*; vulnerable) and fin whale (*Balaenoptera physalus*; vulnerable).

An additional five listed migratory species (including one species also listed as threatened) were identified as potentially occurring or having habitat within the area of influence; the southern right whale (*Eubalaena australis*; also listed as endangered), Antarctic minke whale (*Balaenoptera bonaerensis*), dugong (*Dugong dugon*), Australian snubfin dolphin (*Orcaella heinsohni*) and Indo-Pacific humpback dolphin (*Sousa chinensis*).

Of those species identified in the EPBC Protected Matters search, the pygmy blue whale (endangered) and humpback whale (vulnerable) are most likely to occur in the project area based on historical distribution and habitat preference; albeit in low numbers. The species of primary relevance, and other threatened marine mammal species that may traverse through the area, are discussed in detail below.

**Whales**

*Pygmy Blue Whale*

The blue whale (*Balaenoptera musculus*; endangered) has four distinct sub-species, of which two are found in the southern hemisphere; the pygmy blue whale (*Balaenoptera musculus brevicauda*; Indo-Australian and Tasman-Pacific populations) and the Antarctic blue whale (*Balaenoptera musculus intermedia*; DoE 2015a).

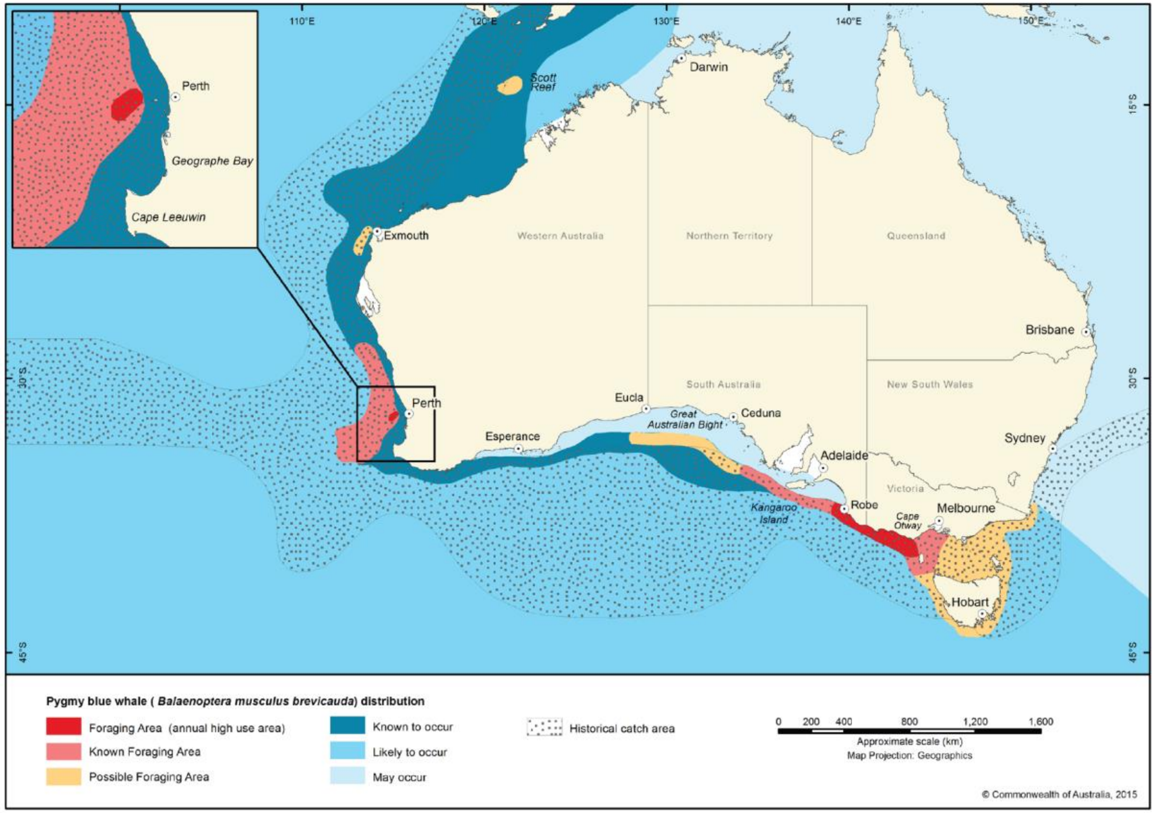
The pygmy blue whale is known to migrate along the WA shelf edge at depths between the 500 m and 1,000 m depth contours from the North West Cape south to Geographe Bay (**Figure 6-23**; DoE 2015a). The species has also been sighted in the NWMR region during offshore surveys and opportunistically (pers. comm. R. Clarke, Monash University, 2018).

A biologically important migration corridor is recognised in the deep offshore waters off WA (**Figure 6-24**; DoEE 2018f). The northerly migration toward the calving grounds near the equator occurs in March/April to June (DoE 2015a). Noise monitoring for the Barossa project, which is located in the Timor Sea approximately 713 km north-east of the Crux platform, detected the presence of blue whales in the months of May to August during their north-bound seasonal migration (McPherson et al. 2016). The southerly migration to the feeding grounds in the high-latitudes of the southern hemisphere occurs in September/October to December (DoE 2015a). Pygmy blue whales appear to travel as individuals or in small groups when making their migrations, based on acoustic data from noise loggers deployed around Scott Reef for the Woodside Browse project (Woodside 2014).

The Perth Canyon off WA and adjacent waters are known biologically important foraging grounds for the pygmy blue whale and are utilised from November to May (**Figure 6-23**; DoE 2015a). A biologically important foraging area also encompasses Seringapatam Reef, Scott Reef and the open waters to the west of these features, as shown in **Figure**

**6-24**. These steep gradient reef-features tend to stimulate upwelling and, in turn, increased productivity (seasonally variable) which provides a favourable foraging area (ConocoPhillips 2018).

Based on the known distribution, preferred feeding habitats and migration pathways of pygmy blue whales, it is considered possible that individuals may be encountered in low numbers in the project area. However, there are no BIAs for the pygmy blue whale within the project area. The migratory and foraging BIAs for pygmy whales are 121 km and 268 km from the Crux platform, respectively.




| | |
|---|---|
| Foraging Area (Annual high use area) | Blue whales are regularly observed feeding on a seasonal basis |
| Known Foraging Area | Known foraging occurs in these areas but is highly variable both between and within seasons |
| Possible Foraging Area | Evidence for feeding is based on limited direct observations or through indirect evidence, such as occurrence of krill in close proximity of whales, or satellite tagged whales showing circling tracks. Blue whales travel through on a seasonal basis, possibly as part of their migratory route |

| | |
|---|---|
| Known to occur | Blue whales are known to occur based on direct observations, satellite tagged whales or based on acoustic detections |
| Likely to occur | Blue whales are likely to occur based on occasional observations in the area and nearby areas |
| May occur | Evidence for the presence of blue whales through strandings or rare observations |
| Historical catch area | Blue whales were caught during the whaling period based on whaling data |

Figure 6-23: Pygmy Blue Whale Distribution around Australia (DoE 2015a)

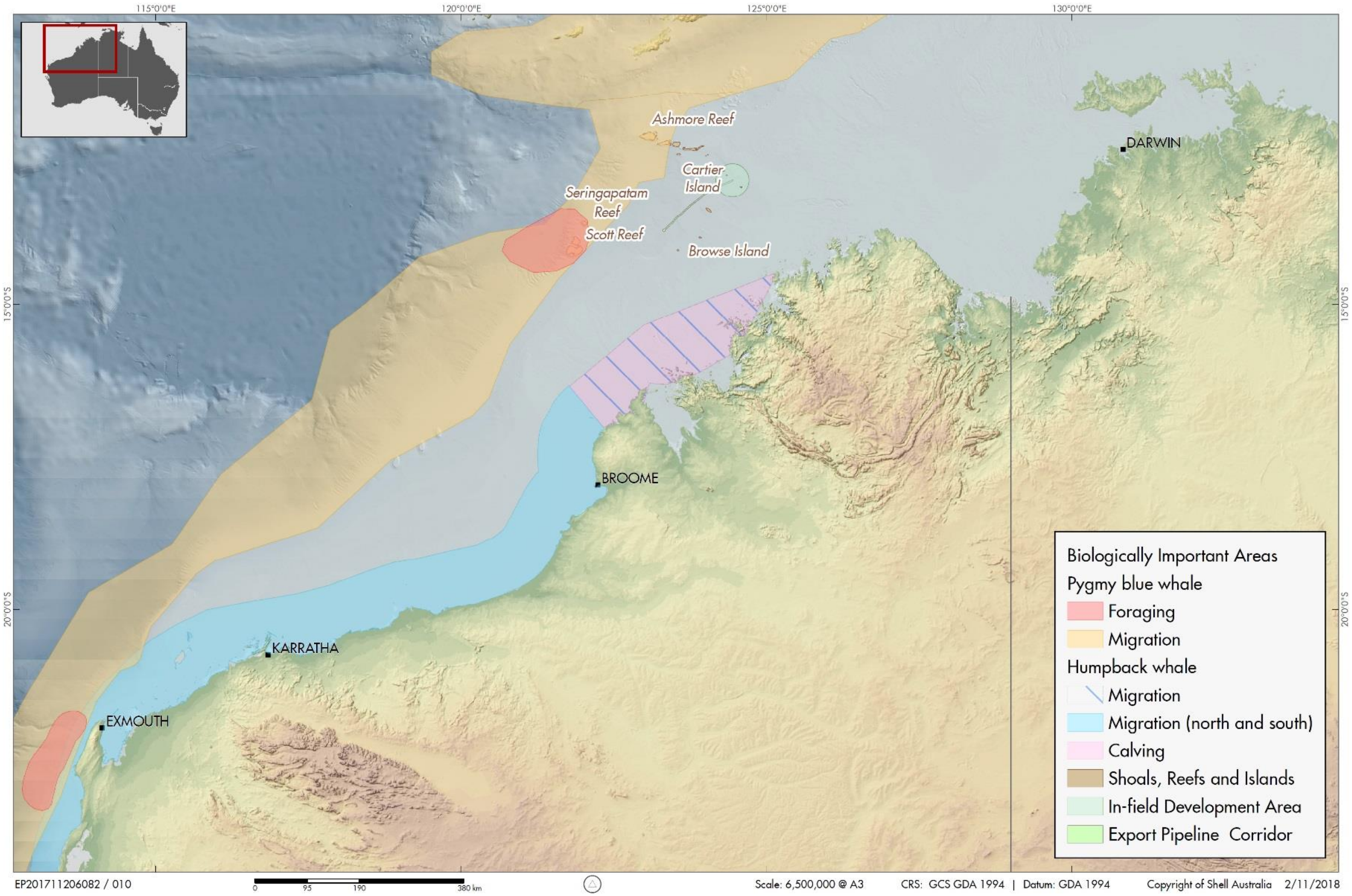



Figure 6-24: Biologically Important Areas for Whales

*Humpback Whale*

The humpback whale (*Megaptera novaeangliae*; vulnerable) has a wide distribution, shown in **Figure 6-25**, with recordings throughout Australian Antarctic waters and offshore from all Australian states (Bannister et al. 1996). The species migrates between summer feeding grounds in Antarctica and winter breeding and calving grounds in the sub-tropical and tropical inshore waters of north-west Australia (Jenner et al. 2001). A biologically important migration area for humpback whales is recognised in nearshore waters (< 100 km) along the WA coast from west of Esperance to 100 km north of Broome (DoEE 2018f; **Figure 6-24**). The northbound migration peaks between late July and early August, and the southbound migration peaks between late August and early September (Jenner et al. 2001).

Humpback whales breed and calve in the NWMR between Broome and the northern end of Camden Sound in the months of June to September each year (DoE 2015b; DoEE 2018g). A biologically important breeding and calving area for humpback whales is recognised in nearshore waters adjacent to the northern half of the Dampier Peninsula and encompasses Camden Sound (**Figure 6-24**; DoEE 2018g). Relatively few humpback whales have been known to travel north of Camden Sound (Jenner et al. 2001). Noise monitoring undertaken for the Barossa project, which is located within the NMR, did not detect any humpback whale calls in the Timor Sea (McPherson et al. 2016).

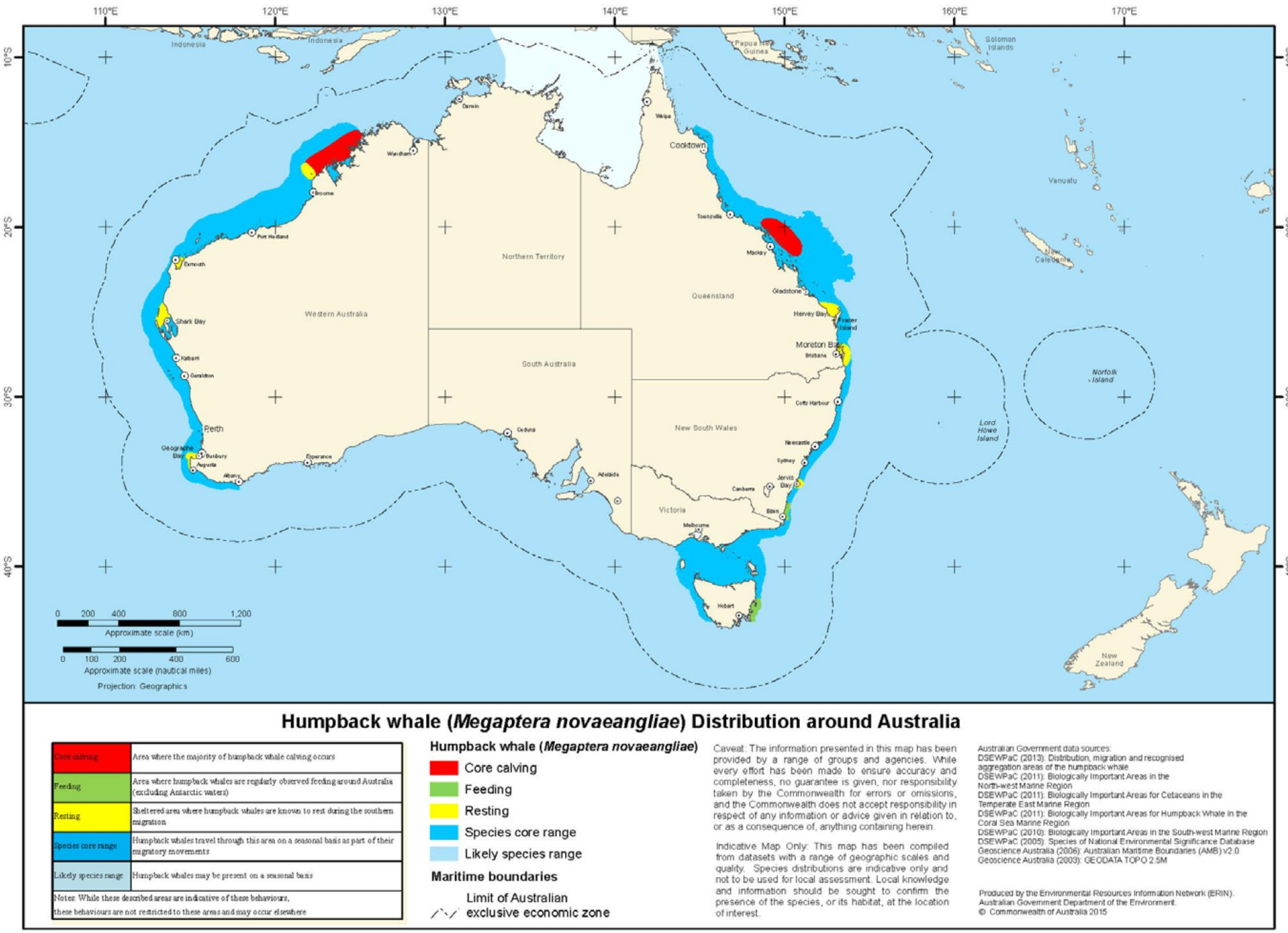



Figure 6-25: Distribution of Humpback Whales around Australia

*Sei Whale*

Sei whales (*Balaenoptera borealis*; vulnerable) have a wide distribution. Rare though sightings are, the species may be seen in coastal and offshore waters throughout Australia, as well as the waters surrounding Christmas and Cocos Keeling Islands (DoEE 2018h; Bannister et al. 1996). The species is able to utilise a diverse range of marine habitats, which has been attributed to a combination of dynamic physical and prey processes (DoEE 2018h).

Sei whale migratory movements are well defined (distinctly north-south) with the species moving between polar, temperate and tropical waters for foraging and breeding. The species feeds intensively between the Antarctic and sub-Antarctic boundary on planktonic crustacea (Bannister et al. 1996; DoEE 2018h). The species does not dive, rather it sinks, and tends to swim at shallower depths comparative to other species (DoEE 2018h). There are no mating or calving areas in Australian waters.

Based on their known distribution and movements, individual sei whales may be encountered in low numbers within the project area.

*Fin Whale*

Fin whales (*Balaenoptera physalus*; vulnerable) are widely distributed from polar to tropical waters and have been recorded in all Australian states, other than NSW and the NT (Bannister et al. 1996).

The species rarely occupies inshore waters and displays well defined migratory movements (essentially north-south) between polar, temperate and tropical waters (Bannister et al. 1996; DoEE 2018i). Migration within Australian waters does not appear to follow a clear route and is thought to occur in summer and autumn. Breeding in the Southern hemisphere occurs in tropical and sub-tropical latitudes between May and July (DoEE 2018i).

Fin whales feed on planktonic crustacea, such as Antarctic krill, and primarily forage in high latitudes (Bannister et al. 1996; DoEE 2018i). Within Australian waters, Antarctic waters and the Bonney Upwelling are thought to be important foraging grounds for this species.

Individual fin whales may be encountered in low numbers within the project area.

*Bryde's Whale*

Bryde's whales (*Balaenoptera edeni*; migratory) distribution encompasses tropical and warm temperate waters with individuals being recorded in all Australian states, except the NT. The species typically moves between 40 °N and 40 °S, with these movements seeming to be primarily linked to prey availability (DoEE 2018j). Bryde's whale are thought to be divided into offshore and onshore forms with the distinction between the two based on prey preference (DoEE 2018j). The offshore form is found in deeper waters (500 m to 1,000 m) and is thought to migrate seasonally in favour of warmer waters in winter months. The onshore form generally inhabits waters < 200 m and displays no distinct migratory movements (DoEE 2018j). The noise monitoring study undertaken for the Barossa project detected Bryde's whales almost year-round (January to October) (McPherson et al. 2016).

Individual Bryde's whales may transit through the project area, based on their known distribution and movements.

*Sperm Whale*

Sperm whales (*Physeter microcephalus*; migratory) occur in deep waters in all oceans, typically remaining at depths of 200 m or greater, and are known to occur throughout Australian waters (Bannister et al. 1996). Key areas for sperm whales are known to occur in WA waters between Cape Leeuwin and Esperance (WA) and along the continental shelf approximately 20 nautical miles (nm) to 30 nm offshore (Bannister et al. 1996). Sperm whales have a diverse diet, although they primarily feed on oceanic squid (Bannister et al. 1996).

Migration patterns vary between sex. Mature females and juveniles are thought to be resident in tropical and subtropical waters throughout the year, whereas mature males are thought to migrate between the tropics and Antarctic (Bannister et al. 1996; DoEE 2018k).

Considering the location of the project and the known distribution of the species, sperm whales may transit through the project area in low numbers.

*Southern Right Whale*

The southern right whale (*Eubalaena australis*; endangered) has been recorded in coastal waters of all Australian states, except the NT, with the northern extent being approximately 16°S (DoEE 2018l). The core coastal range for the species is along the southern coast of Australia from Perth to Sydney. The species is present in these coastal waters between late April and early November, thereafter heading to offshore calving grounds to the south (DoEE 2018l; Carroll et al. 2011). In WA, the species is predominantly found around the southern coastline off southern WA, with the northern extent being around Exmouth (DoEE 2018l; Carroll et al. 2011). Considering the distribution of this species, the southern right whale may occur only within a small portion of the area of influence (i.e. the very southern extent). They are not expected to transit through the project area given its location in offshore waters well north of their known distribution.

*Antarctic Minke Whale*

The Antarctic minke (*Balaenoptera bonaerensis*; migratory) occurs in the waters of all Australian states apart from the NT. Globally, the Antarctic minke whale primarily utilises cold temperate to Antarctic offshore and pelagic waters between 21 °S and 65 °S (Bannister et al. 1996). The majority of individuals seasonally migrate to tropical/sub-tropical breeding grounds, and then to higher latitudes in the summer where they forage primarily on Antarctic krill (DoEE 2018m). Mating occurs between August and September, with the calving season spanning June to July (Bannister et al. 1996). The calving grounds are situated in the warmer waters north of the Antarctic and sub-Antarctic boundary (DoEE 2018m).

The Antarctic minke is considered highly unlikely to occur in the area of influence, given the species preference for colder temperate waters. However, if they are present it is expected that only a few individuals may transit through the area.

*Killer Whale*

Killer whales (*Orcinus orca*; migratory) have a vast global distribution and utilise a wide range of habitats. However, they appear to be primarily concentrated in coastal waters and cooler regions of high productivity (Bannister et al. 1996; DoEE 2018n).

This species is distributed throughout Australian waters, in particular in Tasmanian waters and the waters surrounding Macquarie Island (1,500 km south-south-east of Tasmania) (Bannister et al. 1996; DoEE 2018n). Off Australia, the species is typically observed moving along the continental slope and shelf, and near seal colonies (Bannister et al. 1996). There are no key localities identified within continental Australian waters for this species. Killer whales are carnivores and their diet varies seasonally and regionally (Bannister et al. 1996; DoEE 2018n).

Globally killer whales are known to migrate; however, specific routes and seasonal movement patterns are not known in detail and are thought to relate to prey availability

(Bannister et al. 1996). Migration movements within Australian waters include a summer migration from subantarctic islands to Macquarie Island (DoEE 2018n). Mating occurs year-round and there are no known calving areas in Australian waters (Bannister et al. 1996).

Based on their known distribution and movements, killer whales may be encountered in within the project area; albeit in low numbers.

**Dolphins**

A search of the EPBC Protected Matters database identified three migratory dolphin species as potentially occurring within the area of influence; the spotted bottlenose dolphin (Arafura/Timor Sea populations) (*Tursiops aduncus*), Indo-pacific humpback dolphin (*Sousa chinensis*), and the Australian snubfin dolphin (*Orcaella heinsohni*). These species are described below. No breeding areas for these species are known to occur within the project area, however, BIAs for these species occur within inshore areas of the WA coastline, as shown in **Figure 6-26**.

*Spotted Bottlenose Dolphin*

The spotted bottlenose dolphin (Arafura/Timor Sea populations) (*Tursiops aduncus;* migratory) occurs primarily in continental shelf waters (< 200 m deep), nearshore and in areas with rocky or coral reefs, sandy or soft sediments, or seagrass beds (DSEWPaC 2012c). Small populations also occur in the inshore waters of some oceanic islands. The species also inhabits slightly the deeper and more open water estuarine habitats, when compared to those favoured by the Australian snubfin and humpback dolphins (Reeves and Brownell 2009, cited in DSEWPaC 2012c). Migration patterns for the species in Australia are variable, including of year-round residency in small areas, long-range movements and migration (DoEE 2018o). Due to their tendency to shallow water areas it is unlikely that the species will occur in the project area. No BIAs are known to occur within the project area. However, some BIAs for this species are intersected by the area of influence, as shown in **Figure 6-26**.

*Indo-Pacific Humpback Dolphin*

The Indo-pacific humpback dolphin (*Sousa chinensis;* migratory) is known to occur along the northern Australian coastline from Exmouth in WA to the Queensland/New South Wales (NSW) border region (DoEE 2018p). The species' preferred habitat is shallow (generally < 20 m in depth) coastal, estuarine and riverine (occasional) waters. However, individuals have been observed in shallow waters up to 55 km offshore. The species breeds throughout the year, with calving peaks reported to occur in the spring and summer months across most of their range (DoEE 2018p).

Given the species' preferred habitat, the Indo-pacific humpback dolphin is relevant to the project only in terms of the area of influence, with BIAs within this area shown in **Figure 6-26**.

*Australian Snubfin Dolphin*

The Australian snubfin dolphin (*Orcaella heinsohni;* migratory, also known as the Irrawaddy dolphin, *O. brevirostris*) shares similar habitat preferences with the Indo-Pacific humpback dolphin, occurring in shallow coastal and estuarine waters (typically less than 20 m deep) (DoEE 2018q). However, as with the Indo-pacific humpback dolphin, the species has also been recorded up to 23 km offshore. The Australian snubfin dolphin is likely to occur in higher densities in areas of complex habitat type which provide a variety of prey types (DSEWPaC 2012c). In Australia, the species distribution covers the coastal waters of Queensland, NT and north-western Australia. The population in Australian waters is thought to be continuous with the Papua New Guinea species but separate from populations in Asia.

Within the NWMR the species is likely to migrate and forage off the eastern and western sides of the Cambridge Gulf; to the north and north-west of Cape Londonderry and Cape Talbot; west of Augustus Island; west and north-west of the Buccaneer Archipelago; and Cape Leveque to Broome (DSEWPaC 2012c). Breeding is thought to occur throughout the year for this species.

This species is not expected to occur within the project area due to its habitat preference. As with the other inshore dolphin species known to occur within the area of influence, this species has BIAs along the WA and NT coastlines, as shown in **Figure 6-26**.

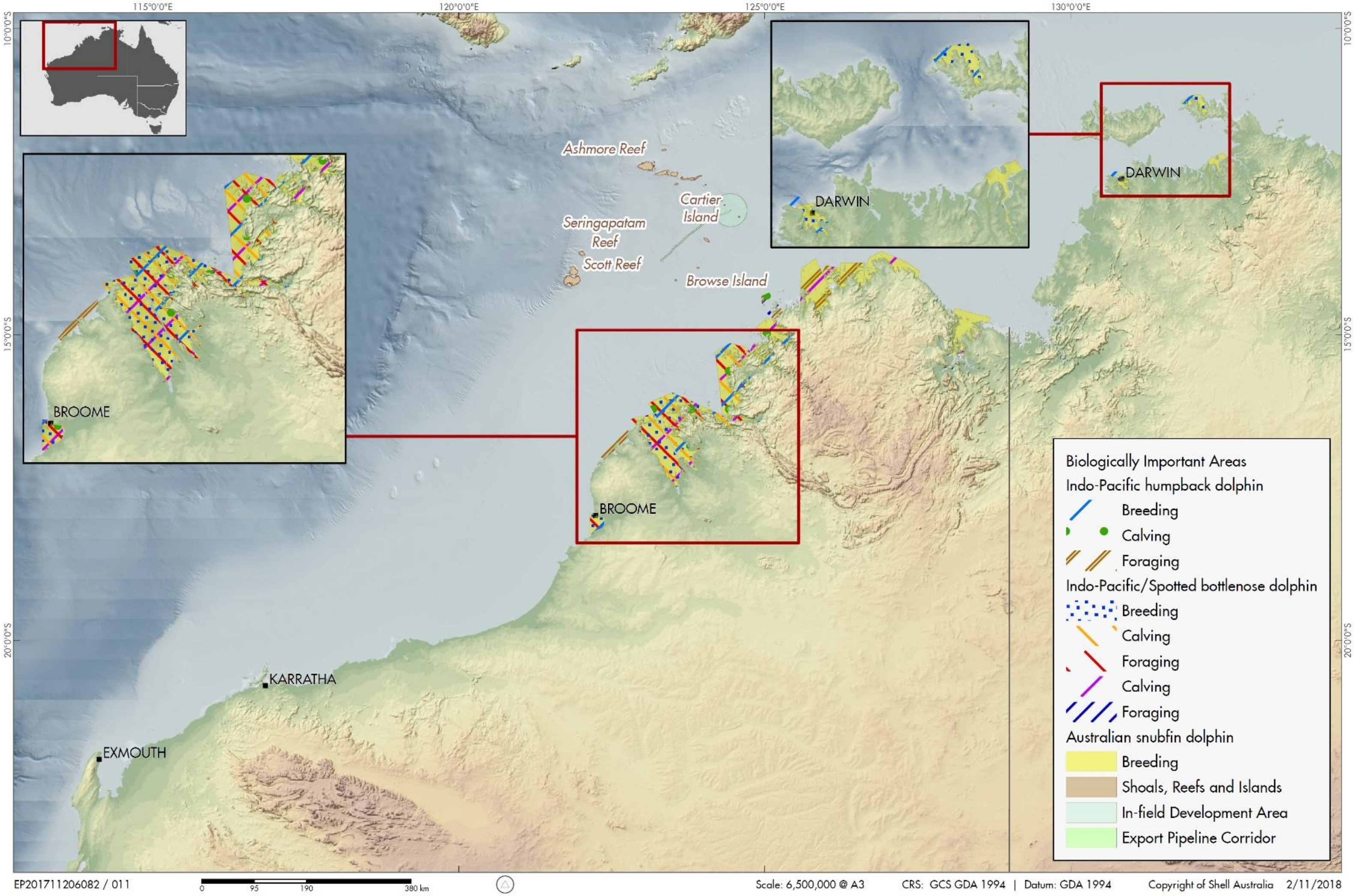



Figure 6-26: Biologically Important Areas for Dolphins

**Dugong**

Dugongs (*Dugong dugon*; migratory) occur in tropical and sub-tropical coastal and island waters broadly coincident with the distribution of seagrasses, which typically occur in shallow intertidal zone areas to water depths of around 25 m (DoEE 2018r). Dugong feeding aggregations tend to occur in large seagrass meadows within wide shallow protected bays, shallow mangrove channels and in the lee of large inshore islands. The movements of most individuals are limited to within tens of kilometres within the vicinity of seagrass beds (National Oceans Office 2004). However, some individuals have been observed to travel large distances of up to 600 km over a few days (National Oceans Office 2004).

Dugongs and areas of potential dugong habitat exist along the majority of WA coastline north from Shark Bay. Within the area of influence there are some small BIAs along the WA coastline, as shown in **Figure 6-27**. Specific areas supporting dugong populations along the WA coast include Shark Bay, Ningaloo and Exmouth Gulf, the Pilbara coast, Eighty Mile Beach and the Kimberley Coast Region (DoEE 2018r).

A small population of approximately 50 individuals exists at Ashmore Reef, which is considered to be genetically distinct from other nearby Australian or Indonesian populations (DoE 2014a). It is possible that the range of this population extends to Cartier Island where individuals maintain a presence (DoE 2014a). Dugongs may also frequent other shallow shoals on the Sahul Banks; however, there has only been a single sighting of this occurrence in 1996 (Whiting and Guinea 2003).

The north coast of the Tiwi Islands (located 624 km east of the in-field development area) is recognised as a key site for the conservation of dugongs (PWSNT 2003). A well-known major dugong aggregation of approximately 4,400 individuals occurs in waters seaward (within approximately 50 km) of the Tiwi Islands and ranks in the top eight of dugong populations in Australia (PWSNT 2003).

Considering the habitat preference of the species, it is unlikely that dugongs will transit the offshore waters of the project area.

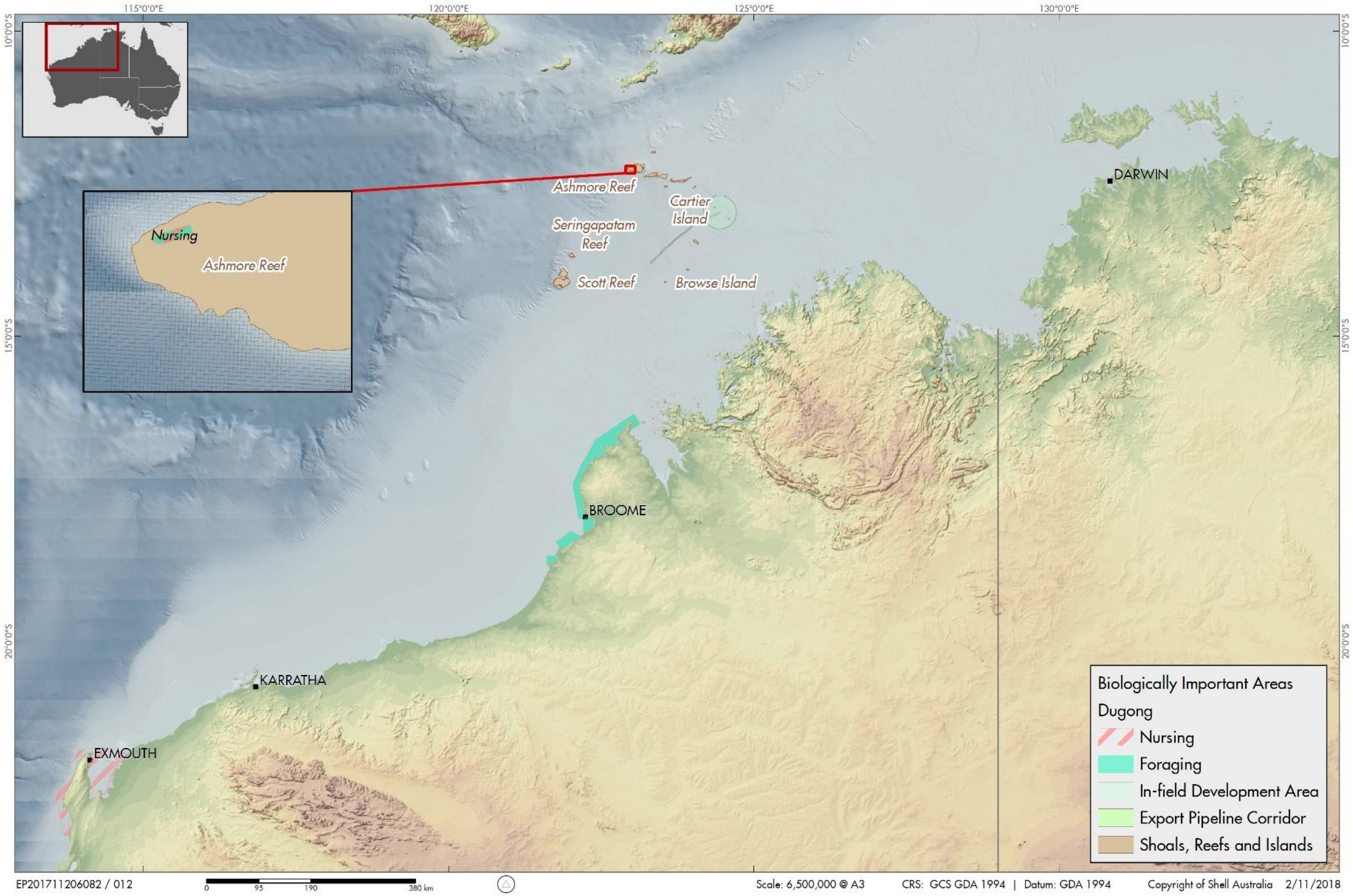



Figure 6-27: Biologically Important Areas for Dugongs

**EPBC Management/Recovery Plans and Conservation Advices**

The EPBC Management/Recovery Plans and conservation advices for the marine mammal species identified in the EPBC Protected Matters searches for the project area and area of influence are summarised in **Table 6-7**.

Table 6-7: Summary of EPBC Management/Recovery Plans and Conservation Advices Relevant to Marine Mammals

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/Conservation Advice | Relevant ? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Blue whale[P] | Conservation management plan for the blue whale; A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015–2025 (October 2015) (DoE 2015a) | Vessel disturbance | Y | Section 8.4.1 |
| | | Noise interference | Y | Section 8.4.3 |
| | | Habitat modification including presence of oil and gas platforms/rigs, marine debris infrastructure and acute/chronic chemical discharge | Y | Section 8.4.1, Section 8.4.7, Section 8.4.8, Section 8.4.9 |
| | | Whaling | N | The key threats are outside the scope of this OPP |
| | | Climate variability and change | | |
| Humpback whale[P] | Conservation advice on humpback whale (*Megaptera novaeangliae*) (October 2015) (DoE 2015b) | Vessel disturbance and strike | Y | Section 8.4.1 |
| | | Noise interference | Y | Section 8.4.3 |
| | | Entanglement – marine debris | Y | Section 8.4.7 |
| | | Whaling | N | The key threats are outside the scope of this OPP |
| | | Climate and oceanographic variability and change | | |
| | | Overharvesting of prey | | |
| | | Habitat degradation including coastal development and port expansion | | |
| | | Entanglement – commercial fisheries or aquaculture equipment, and shark safety equipment | | |
| Sei whale[P] | Conservation advice on sei whale (*Balaenoptera borealis*) (October 2015) (DoE 2015c) | Vessel strike | Y | Section 8.4.1 |
| | | Anthropogenic noise and acoustic disturbance | Y | Section 8.4.3 |
| | | Pollution (persistent toxic pollutants) | Y | Section 8.4.8, Section 8.4.9 |
| | | Climate and oceanographic variability and change | N | The key threats are outside the scope of this OPP |
| | | Habitat degradation including pollution (increasing port expansion and coastal development) | | |
| | | Prey depletion due to fisheries (potential threat) | | |
| | | Resumption of commercial whaling (potential threat) | | |
| Fin whale[P] | Conservation advice on fin whale (*Balaenoptera* | Vessel strike | Y | Section 8.4.1 |
| | | Anthropogenic noise and acoustic disturbance | Y | Section 8.4.3 |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/Conservation Advice | Relevant ? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| | *physalus*) (October 2015) (DoE 2015d) | Pollution (persistent toxic pollutants) | Y | Section 8.4.8, Section 8.4.9 |
| | | Climate and oceanographic variability and change | N | The key threats are outside the scope of this OPP |
| | | Habitat degradation including pollution (coastal development, increasing port expansion and aquaculture) | | |
| | | Fisheries catch, entanglement and bycatch | | |
| | | Resource depletion due to fisheries (potential threat) | | |
| | | Resumption of commercial whaling (potential threat) | | |
| Southern right whale | Conservation management plan for the southern right whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2011–2021 (DSEWPaC 2012d) | Vessel disturbance and strike | N | The EPBC Protected Matters search has not recorded the species within the project area. Consideration is given to this species in the context of habitat degradation from pollution associated with emergency/ unplanned events (Section 8.4.9). |
| | | Entanglement – marine debris | N | |
| | | Noise interference | N | |
| | | Habitat modification including infrastructure/coastal development and energy production facilities, and acute/chronic chemical discharge | Y | |
| | | Whaling | N | The key threats are outside the scope of this OPP |
| | | Climate variability and change | | |
| | | Overharvesting of prey | | |

[P] The species was identified as potentially occurring or having habitat in the project area.

### 6.5.6.2 Marine Reptiles

A range of marine reptiles (turtles and sea snakes) were identified as potentially occurring or having habitat in the project area and area of influence. These are discussed further below.

**Marine Turtles**

A search of the EPBC Act Protected Matters database identified six threatened species of marine turtle that may occur in the project area and area of influence; the flatback turtle (*Natator depressus*; vulnerable), green turtle (*Chelonia mydas*; vulnerable), olive-ridley turtle (*Lepidochelys olivacea*; endangered), hawksbill turtle (*Eretmochelys imbricata*; vulnerable), loggerhead turtle (*Caretta caretta*; endangered), and leatherback turtle (*Dermochelys coriacea*; endangered).

Turtles are oceanic species except during seasonal onshore nesting periods, which are species-dependent and vary along the north Australian coastline (Commonwealth of Australia 2017b). While the incubation time between turtle nesting and emergence of hatchlings varies between species, it is generally about 2 months (Commonwealth of

Australia 2017b). Female turtles also exhibit an internesting phase in which they spend 2–3 months in shallow waters in the vicinity of the nesting beach or rookery while they produce the next clutch of eggs (Guinea 2013; Commonwealth of Australia 2017b). The female turtles will rest on the seabed during the internesting period but are not known to feed (ConocoPhillips 2018).

The project area does not contain any emergent land or shallow features that may be of importance to nesting or foraging turtles. Therefore, turtles are unlikely to be present in the area in significant numbers. However, low numbers are likely to transit the project area as they move from nesting beaches and offshore areas.

The broad distribution and habitats of each marine turtle species is summarised below, with further detail on BIAs and habitat critical to the survival of these species (based on geographically distinct genetic stocks) also provided in **Table 6-8** and **Table 6-9**, respectively:

- green turtle – within Australian waters green turtles are predominately found off the WA, NT, Queensland coastlines (Commonwealth of Australia 2017b). The green turtle is the most common marine turtle breeding in the NWMR and WA supports one of the largest remaining green turtle populations in the world (DSEWPaC 2012e). The species is primarily herbivorous and forages on algae, seagrass and mangroves, including where these habitats exist at offshore coral reef habitats (Commonwealth of Australia 2017b). Green turtles are also known to travel large distances of up to 2,600 km between nesting and feeding areas (DSEWPaC 2012e).
- loggerhead turtle – the species is known to range along most of the Australian coastline and throughout the NWMR (Commonwealth of Australia 2017b). Loggerhead turtles are carnivorous and mainly feed on benthic invertebrates in a wide range of habitats ranging from nearshore to 55 m in depth (Commonwealth of Australia 2017b).
- flatback turtle – the species is known to occur along the WA, NT, Queensland coastlines, and forages widely across the Australian continental shelf and into the continental waters off Indonesia and Papua New Guinea (Commonwealth of Australia 2017b). Flatback turtles are primarily carnivorous and feed predominantly on soft-bodied invertebrates (Commonwealth of Australia 2017b). Flatback turtles that nest within the Pilbara region typically migrate along the continental shelf to foraging grounds as far north as Darwin at the end of the nesting season (Commonwealth of Australia 2017b).
- hawksbill turtle – hawksbill turtles predominately occur along the northern WA, NT and northern Queensland coastlines. Hawksbill turtles are omnivorous and feed on algae, sponges, soft corals and soft bodied-invertebrates. This species is typically associated with rocky and coral reef habitats and is expected to be found foraging within these habitats along the WA coastline, from Shark Bay to the northern extent of the NWMR (Commonwealth of Australia 2017b).
- olive ridley turtle – olive ridley turtles are primarily carnivorous and feed predominantly on soft-bodied invertebrates (Commonwealth of Australia 2017a). The species is known to feed in water depths between 15 m and 200 m, and to migrate up to 1,130 km between their nesting and foraging grounds (Whiting et al. 2005). Nesting is known to occur in the NT and on western Cape York (Queensland). Low density nesting has also been described on the Kimberley coast (Commonwealth of Australia 2017b). This species appears to remain on the Australian continental shelf into waters off Indonesia (Commonwealth of Australia 2017b).
- leatherback turtle – leatherback turtles are known to forage and migrate throughout the open offshore waters of Australia, with foraging more common in along the east

coast and the Bass Strait. Records of leatherback turtle nesting in Australia are sparse and limited to the Cobourg Peninsula and Queensland coast (Commonwealth of Australia 2017b). There have been no confirmed accounts of nesting on beaches along the WA coastline. Leatherback turtles eat almost exclusively jellyfish and are pelagic throughout their life in oceanic waters around Australia (Commonwealth of Australia 2017b).

BIAs

BIAs for foraging, breeding, nesting and internesting activities identified for marine turtle species in the area of influence are listed in **Table 6-8** (Commonwealth of Australia 2017b) and shown in **Figure 6-28**.

Table 6-8: BIAs for Marine Turtles

| BIA | General Location(s) |
|---|---|
| *Green Turtle* | |
| Internesting/nesting | Islands north-east of Cobourg Peninsula, north-west of Melville Island, Cassini Island, Lacepede Island, Islands in Dampier Archipelago, Barrow Island, Montebello Islands, North West Cape, North and South Muiron Island, Scott Reef, Ashmore Reef, Cartier Island. |
| Foraging | West Arnhem Land coastal and island areas, Kakadu National Park coastal areas, Joseph Bonaparte Gulf, Montgomery Reef, Ashmore Reef, James Price Point, De Grey River area out to Bedout Island, Dampier and Pilbara inshore coastal area and islands (including Barrow Island and reef habitats west of the Montebello Islands). |
| *Loggerhead Turtle* | |
| Internesting/nesting | Dampier Archipelago Islands, Karratha coastal area and nearby Islands, Montebello Islands, Muiron Island, Ningaloo and Jurabi coastline. |
| Foraging | Western Joseph Bonaparte Depression, James Price Point, De Grey River area out to Bedout Island. |
| *Flatback Turtle* | |
| Internesting/nesting | Coastal waters and islands adjacent to the Pilbara coastline from Exmouth to Broome, Lacepede Island, Cape Domett, Darwin coastal area and Cobourg Peninsula extending to include Melville Island. |
| Foraging | Western Joseph Bonaparte Depression, James Price Point, North Turtle Island, Dampier and Pilbara inshore islands. |
| *Hawksbill Turtle* | |
| Internesting/nesting | Islands north-east of Cobourg Peninsula, Greenhill Island, Ashmore Reef, Scott Reef, Islands adjacent to the Pilbara and Dampier coastline (including Barrow, Thevenard and Montebello Islands), Ningaloo coast and Jurabi coast. |
| Foraging | De Grey River area out to Bedout Island, Dampier and Pilbara inshore islands. |
| *Olive-ridley Turtle* | |
| Internesting | Islands north-east of Cobourg Peninsula, Greenhill Island, Bathurst and Melville Islands, Fog Bay to Cox Peninsula. |
| Foraging | Western Joseph Bonaparte Depression, northern Joseph Bonaparte Depression, Joseph Bonaparte Gulf. |
| *Leatherback Turtle* | |
| Internesting/nesting | Cobourg Peninsula |

Habitat Critical to the Survival of Marine Turtles

Habitat identified as critical to the survival of marine turtles which occur within the area of influence are listed in **Table 6-9** (Commonwealth of Australia 2017b) and shown in **Figure 6-29**.

Table 6-9: Habitat Critical to the Survival of Marine Turtles

| Genetic Stock | Habitat Critical Area within Area of Influence | Internesting Buffer | Nesting Season |
|---|---|---|---|
| *Green Turtle* | | | |
| Cobourg Peninsula | Black Point to Smith Point, Croker Island and McCluer Island Group | 20 km radius | October to April |
| North West Shelf | Adele Island, Maret Island, Cassini Island, Lacepede Islands, Barrow Island, Montebello Islands (all with sandy beaches), Serrurier Island, Dampier Archipelago, Thevenard Island, Northwest Cape, Ningaloo Coast | 20 km radius | November to March |
| Ashmore Reef | Ashmore Reef and Cartier Reef | 20 km radius | All year<br>(peak between December and January) |
| Scott-Browse | Scott Reef (Sandy Islet) and Browse Island | 20 km radius | November to March |
| Cocos Keeling | Cocos (Keeling) Islands and within the Pulu Keeling National Park | 20 km radius | October to April |
| *Loggerhead Turtle* | | | |
| WA | Dirk Hartog Island, Muiron Islands, Ningaloo Coast | 20 km radius | November to May |
| *Flatback Turtle* | | | |
| Pilbara | Montebello Islands, Mundabullangana Beach, Barrow Island, Cemetery Beach, Dampier Archipelago (including Delambre Island and Huay Island), coastal islands from Cape Preston to Locker Island. | 60 km radius | October to March |
| South-west Kimberley | Eighty Mile Beach, Eco Beach, Lacepede Islands | 60 km radius | May to July |
| Unknown genetic stock Kimberley, WA | Maret Islands, Motilivet Islands, Cassini Island, Coronation Islands (includes Lamarck Island), Napier-Broome Bay Islands (West Governor Island, Sir Graham Moore Island – near Kalumbaru), Champagny, Darcy and Augustus Islands (Camden Sound) | 60 km radius | |
| Cape Domett | Cape Domett, Lacrosse Island | 60 km radius | All year<br>(peak between July and September) |
| Arafura Sea | Field Island, Bare Sand Island, Tiwi Islands, Cobourg Peninsula, Wessel Islands, Crocodile Island Group | 60 km radius | All year<br>(peak between June and September) |
| *Hawksbill Turtle* | | | |
| WA | Dampier Archipelago (including Rosemary Island and Delambre Island), Montebello Islands (including Ah Chong Island, South East Island and Trimouille Island), Lowendal Islands (including Varanus Island, Beacon Island and Bridled Island), Sholl Island | 20 km radius | October to February |
| *Olive Ridley Turtle* | | | |

| Genetic Stock | Habitat Critical Area within Area of Influence | Internesting Buffer | Nesting Season |
|---|---|---|---|
| NT | Tiwi Islands, McCluer Island group, Cobourg Peninsula, Crocodile Island Group | 20 km radius | All year (peak between April and August) |
| Unknown genetic stock Kimberley, WA | Prior Point, Vulcan Island, Darcy Island, Llangi, Cape Leveque | 20 km radius | May to July |
| *Leatherback Turtle* | | | |
| Australia | Cobourg Peninsula and adjacent West Arnhem coastline to the east (including adjacent islands (e.g. Wessel Islands and Elcho Island)) | 20 km radius | December-January |

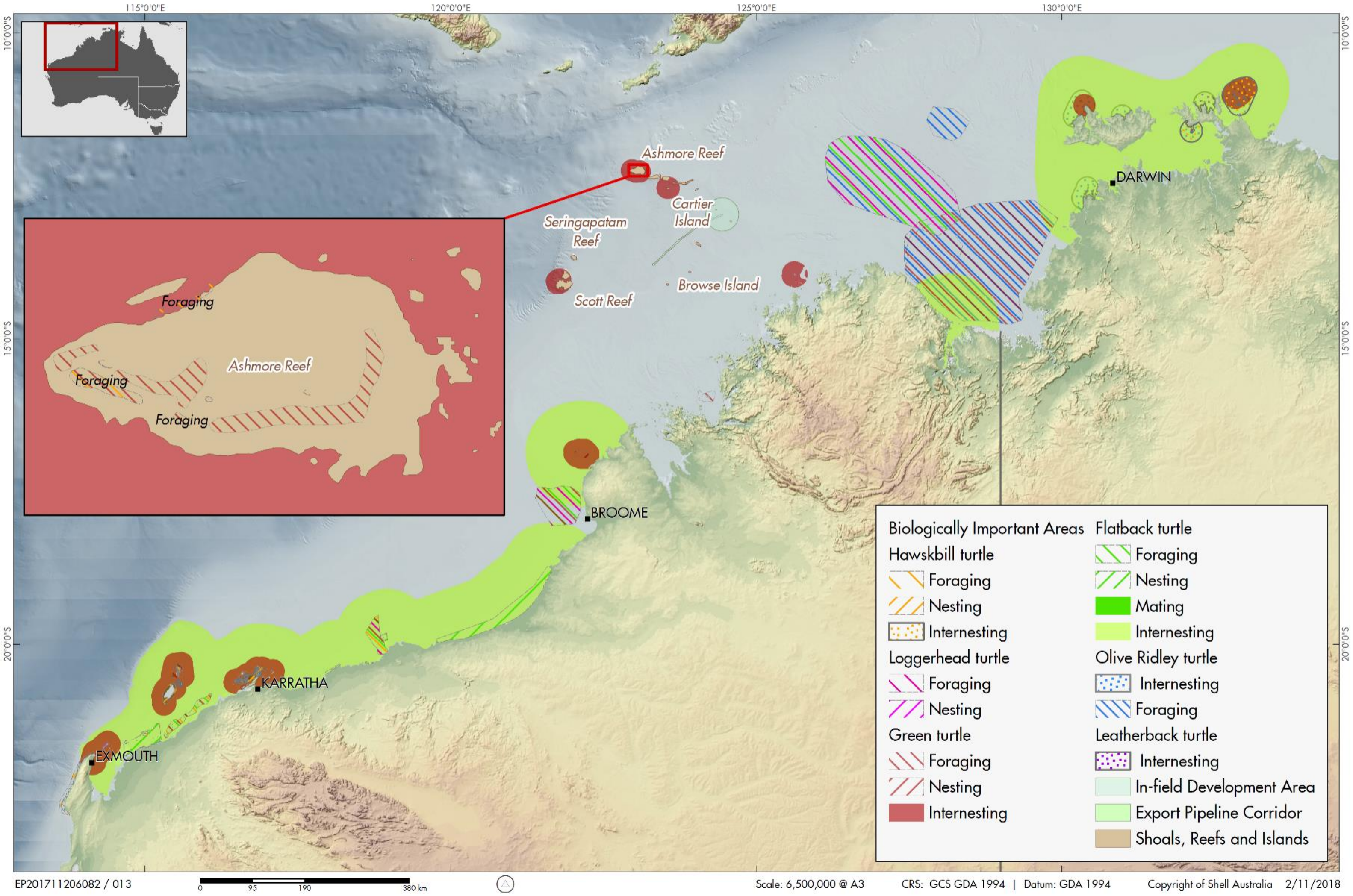



Figure 6-28: Biologically Important Areas for Marine Turtles

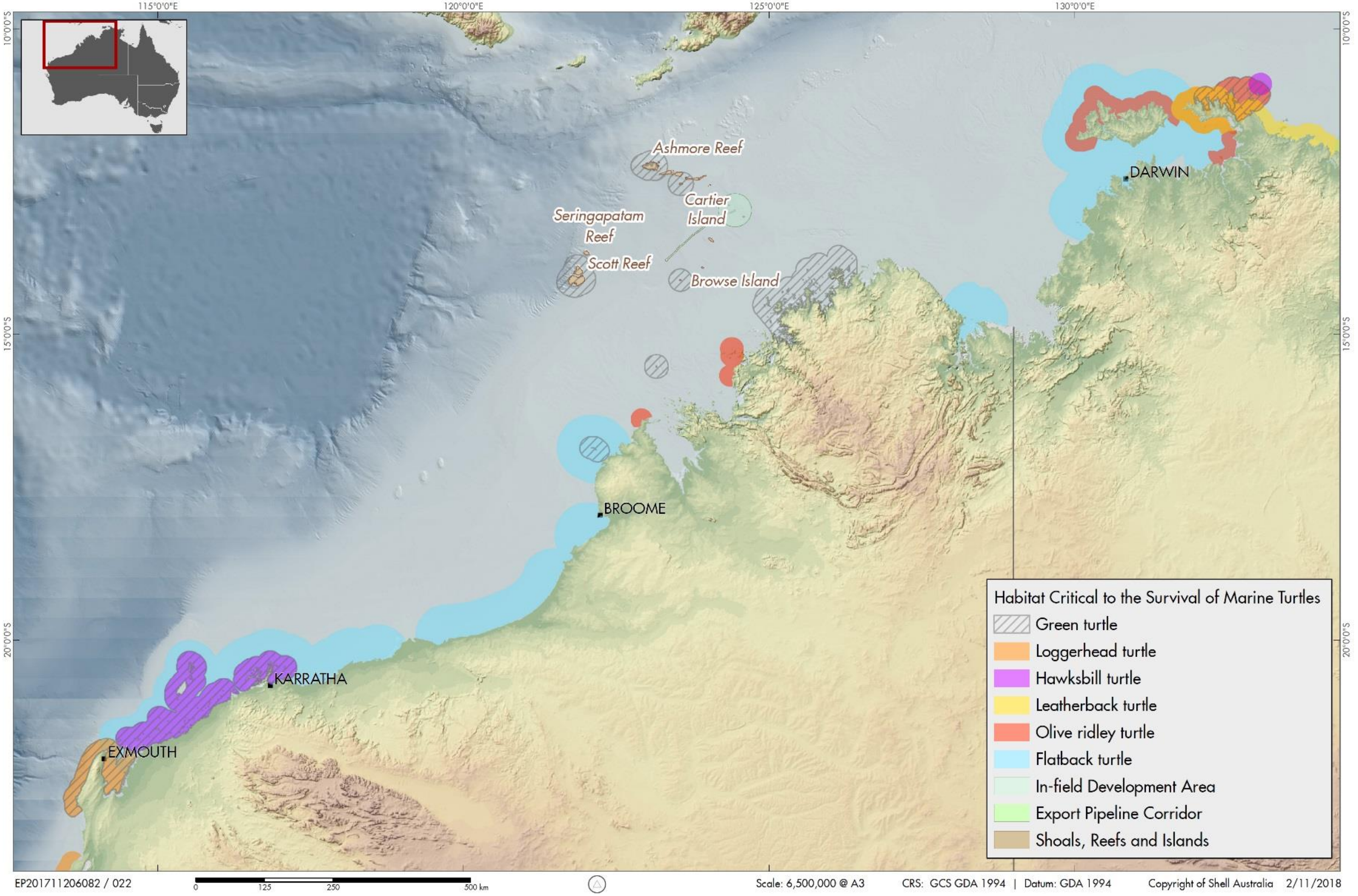



Figure 6-29: Habitat Critical to the Survival of Marine Turtles

**Sea Snakes**

A search of the EPBC Act Protected Matters database identified 13 sea snake species as potentially occurring in the project area, including two which are listed as threatened; the short-nosed sea snake (*Aipysurus apraefrontalis*; critically endangered) and Leaf-scaled sea snake (*Aipysurus foliosquama*; critically endangered). An additional 12 species may occur within the area of influence. All sea snakes in Australia are listed as protected species under the EPBC Act. Twenty-five species of sea snake are known to occur in the NWMR, including eight endemic species (Guinea 2006). Specific locations within the NWMR considered significant for specific species of sea snake are Shark Bay, the Pilbara coast, and the Kimberley coast (DSEWPaC 2012e).

Sea snakes generally inhabit shallow inshore regions and islands, both near the coastline and offshore, as they feed in shallow, benthic habitats. Sea snakes also inhabit waters surrounding offshore atolls and shoals/banks in the Timor Sea (Guinea 2013). Most sightings of sea snakes have been in water depths of 10 m to 50 m deep (RPS 2010), however, some species are known to dive to deeper depths. The non-pelagic sea snake species rarely, if ever, dive deeper than 100 m (Heatwole and Seymour 1975).

The distribution and movements of sea snakes vary between species. Some species, for example the pelagic yellow-bellied sea snake, traverse large distances in open offshore waters while others, such as the olive sea snake, are typically resident to a particular area. Sea snake species that reside on reefs do not actively disperse or migrate between reefs and are found to be present year-round at most reefs on the Sahul Shelf (Guinea and Whiting 2005). A survey undertaken by AIMS (Heyward et al. 2012) identified 117 sea snake individuals across nine submerged shoals, which are located within an approximately 150 km radius of the in-field development area. Of these individuals, 66 were identified as the olive sea snake, four as the spotted sea snake and the remaining individuals were unable to be identified. A study by Guinea et al. (2013) identified an additional eight common reef-dwelling species of sea snake historically reported to occur on Ashmore Reef, with some of these species also occurring on Cartier Island, Hibernia Reef, Scott Reef and Seringapatam Reef.

The short-nosed sea snake and the leaf-scaled sea snake were previously thought to be short-range endemic species restricted to Ashmore Reef and Hibernia Reef, which are located approximately 155 km and 105 km north-west of the Crux platform, respectively. However, two short-nosed sea snakes and two leaf-scaled sea snakes have recently been sighted at Ningaloo Reef, some 1,500 km south-south-west of the project area (D’Anastasi 2016). A leaf-scale sea snake was also observed in seagrass meadows in Shark Bay (D’Anastasi 2016). These species prefer the reef flats or shallow waters along the outer reef edge in water depths to 10 m (DSEWPaC 2010a, 2010b). Whilst once relatively common at Ashmore and Hibernia reefs, the species have not been recorded at these locations since the late 1990s/2001, despite an increase in survey effort (DSEWPaC 2010a, 2010b). The decline of sea snakes at Ashmore Reef is likely multi-faceted and has been linked to ecosystem degradation as a result of major coral bleaching events in the 1990s.

Based on known species distributions and habitat preferences of sea snakes, it is expected sea snakes may transit through the open waters of the project area, with any individuals expected to be in the vicinity of the shoals within the in-field development area.

**Crocodiles**

While not identified in the project area EPBC Protected Matter searches, two species of crocodile were noted as potentially occurring in the area of influence; the salt-water crocodile (*Crocodylus porosus*) and freshwater crocodile (*Crocodylus johnstoni*). The salt-water crocodile was originally listed under the EPBC Act to regulate commercial hunting, which was causing significant population declines (DoEE 2018s).

The salt-water crocodile occurs within the nearshore marine and estuarine waters of the Kimberley coast (DoEE 2018s). Larger populations within the major river systems of the Kimberley occur in the rivers draining into the Cambridge Gulf, the Prince Regent and Roe River systems of the east and northwest Kimberley (DEC 2009b). There is limited availability of nesting habitat for this species within its distribution, with only the Ord, King and Roe River systems typically providing suitable nesting vegetation for the species (DEC 2009b).

The freshwater crocodile is more widely distributed over the coastal and mainland areas of northern Australia than the salt-water crocodile (DoEE 2018t). The species occupies the same river systems as the salt-water crocodile in the Kimberley region and areas which exclude the larger salt-water crocodiles (DEC 2009b). Freshwater crocodiles breed in all of the river systems in which it occurs (DEC 2009b).

There are no BIAs for the salt-water or freshwater crocodile within the project area and, given the distance of the project area from the WA coastline (approximately 190 km), it is highly unlikely that individuals will transit through the project area.

#### EPBC Management/Recovery Plans and Conservation Advices

The EPBC Management/Recovery Plans and conservation advices for the marine reptile species identified in the EPBC Protected Matters searches for the project area and area of influence are summarised in **Table 6-10**.

Table 6-10: Summary of EPBC Management/Recovery Plans and Conservation Advices Relevant to Marine Reptiles

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/Recovery Plan/Conservation Advice | Relevant ? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Loggerhead turtle[P]<br>Green turtle [P]<br>Leatherback turtle[P]<br>Hawksbill turtle[P]<br>Olive ridley turtle [P]<br>Flatback turtle[P] | Recovery plan for marine turtles in Australia 2017-2027 (June 2017) (Commonwealth of Australia 2017b)<br><br>Conservation advice on leatherback turtle (*Dermochelys coriacea*) (DEWHA 2009a) | Habitat modification | Y | Section 8.4.1 |
| | | Vessel disturbance | Y | Section 8.4.1 |
| | | Light pollution | Y | Section 8.4.2 |
| | | Noise interference | Y | Section 8.4.3 |
| | | Marine debris | Y | Section 8.4.7 |
| | | Chemical and terrestrial discharge | Y | Section 8.4.8, Section 8.4.9 |
| | | Climate change and variability | N | The key threats are outside the scope of this OPP |
| | | International take | | |
| | | Terrestrial predation | | |
| | | Fisheries bycatch | | |
| | | Indigenous take | | |
| | | Recreational activities | | |
| | | Diseases and pathogens | | |
| Short-nosed sea snake<br>Leaf-scaled sea snake | Conservation advice on short-nosed sea snake (*Aipysurus apraefrontalis*) (DSEWPaC 2010a)<br><br>Conservation advice on leaf-scaled sea | Degradation of reef habitat, primarily as a result of coral bleaching (principle threat) | N | The key threat is outside the scope of this OPP |
| | | Oil and gas exploration | N | The EPBC Protected Matters search has not recorded the species within the |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/Recovery Plan/Conservation Advice | Relevant ? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| | snake (*Aipysurus foliosquama*) (DSEWPaC 2010b) | | | project area. Consideration is given to this species in the context of habitat degradation from pollution associated with emergency/ unplanned events (Section 8.4.9). |
| | | Incidental catch and death in commercial prawn trawling fisheries (relevant to the NWMR) | N | The key threats are outside the scope of this OPP |
| | | Unsustainable and illegal fishing practices (Ashmore Reef region) | | |

[P] The species was identified as potentially occurring or having habitat in the project area.

### 6.5.6.3 Birds

A number of seabirds and migratory shorebirds are known to occur within the NWMR as they range over large distances to forage over the open ocean (DSEWPaC 2012f). The EPBC Protected Matters search identified 12 bird species as potentially occurring within the project area, five of which are threatened; the curlew sandpiper (*Calidris ferruginea*; critically endangered), eastern curlew (*Numenius madagascariensis*; critically endangered), Australian lesser noddy (*Anous tenuirostris melanops*; vulnerable), red knot (*Calidris canutus*; endangered) and Abbott's booby (*Papasula abbotti*; endangered). These species are discussed below.

An additional 48 listed migratory species (including nine threatened species) were identified to potentially occur within the area of influence. There are twelve bird species with BIAs within the area of influence, these are indicated in **Table 6-11** and **Figure 6-30**. Most migrant birds are expected to fly over the regional area as part of their large-scale transitory movements and are unlikely to land on the sea for significant periods of time (ConocoPhillips 2018). Considering this, and the general absence of landing areas at a regional offshore scale, the majority of seabird activity is likely to comprise foraging and migration pathways, as opposed to seabird stopover and roosting points during annual migrations. Whilst seabirds spend much of their lives at sea, migratory shorebirds overfly offshore areas during migratory periods and typically do not interact with the sea surface (DSEWPaC 2012f; ConocoPhillips 2018). Migratory wetland species also do not interact with open offshore waters. However, these species may land on offshore oil and gas infrastructure, especially during inclement weather, while flying between land masses (ConocoPhillips 2018).

No emergent land exists in the shoals or surrounding offshore areas in the immediate vicinity of the project area to support breeding populations of seabirds or migratory shorebirds. The nearest shorelines to the project area being Cartier Island and Ashmore Reef, which are located 105 km and 155 km north-west of the Crux platform, respectively. More broadly, Scott Reef and Browse Island may provide additional connectivity for shorebirds of the NWMR (DSEWPaC 2012f).

**Curlew Sandpiper**

The curlew sandpiper (*Calidris ferruginea*; critically endangered) has a vast distribution, being recorded along the coasts of all Australian states and territories (DoEE 2018u). The species preferred habitat is intertidal mudflats in sheltered coastal areas as they forage in nearshore waters or mud at the edge of wetlands (DoEE 2018u). However, they are also widespread inland; albeit in smaller numbers. The curlew sandpiper migrates along the East Asian-Australasian Flyway (Flyway) from their breeding grounds in Siberia to Australia, generally arriving in Australia around late August/early September and departing by mid-April (DoEE 2018u). Some non-breeding individuals may not undertake the migration northward but stay in Australia (DoEE 2018u).

Based on the known distribution, preferred feeding and roosting habitats, it is considered highly unlikely that individuals will interact with the project area due to the absence of any land.

**Eastern Curlew**

The eastern curlew (*Numenius madagascariensis*; critically endangered) is the world's largest species of shorebird (Menkhorst et al. 2017; DoEE 2018v). The species is restricted to the Flyway, undertaking an annual migration to breeding grounds in Russia and north-eastern China, before returning to Australia in August to forage, primarily in intertidal mudflats on larger prey items such as crab (Bamford et al. 2008; DoEE 2018v; Menkhorst et al. 2017). There are two internationally important non-breeding sites in northern WA; Roebuck Bay and Eighty Mile Beach (Bamford et al. 2008).

Considering the species preferred habitat and diet, the eastern curlew is very unlikely to land or interact with offshore waters during its migration through the Flyway.

**Australian Lesser Noddy**

The Australian lesser noddy (*Anous tenuirostris melanops*; vulnerable) is a tropical species of tern endemic to Australia (DoEE 2018w; DEWHA 2015a). Whilst the Australian lesser noddy has a large range, the species utilises primarily a small area in Houtman Abrolhos for breeding (DoEE 2018w; DEWHA 2015a). The species is also known to breed in small numbers at Ashmore Reef (Menkhorst et al. 2017). Individuals generally remain in close proximity to the breeding islands throughout the year. Therefore, while some individuals may occur within the project area, they are not expected to occur in significant numbers.

**Red Knot**

The red knot (*Calidris canutus*; endangered) is an omnivorous wading bird which utilises the intertidal mudflats, sandflats and sandy beaches of sheltered coastal areas, estuaries, bays and other similar marine habitats. The red knot may also utilise saline wetlands but rarely freshwater water sources (DoEE 2018x). The red knot is present throughout coastal and offshore Australia, including Christmas and Cocos Keeling Islands. Notably, large numbers of red knot are regularly recorded in the north-west of Australia (specifically at 80 Mile Beach and Roebuck Bay) and the species is present along the Ningaloo coast and at Lake Macleod (DoEE 2018x; Bamford et al. 2008).

While the species utilises the Flyway, the exact migration route of Australian populations of red knot to their Arctic breeding grounds is unknown (DoEE 2018x; Watkins 1993). It is, however, thought that individuals may begin the journey by moving south across the west Pacific Ocean and then north along the east Asian coast (DoEE 2018x). The species is thought to make minimal stop overs during this migration. At the end of the breeding season the species returns south, arriving in northern Australia in late August to early September to take up residence, as well as settling in other areas primarily in eastern Australia and New Zealand (DoEE 2018x; Watkins 1993).

Given the species' habitat preference, the red knot is unlikely to land or interact with offshore waters during its migration over the Timor Sea.

**Abbott's Booby**

The Abbott's booby (*Papasula abbotti*; endangered) spends the majority of its time at sea and generally only comes ashore to breed. Within Australia, the Abbott's booby breeds exclusively on Christmas Island, displaying a preference for nesting in the forests on the island and foraging in the surrounding waters (DEWHA 2015b). Recent population estimates on Christmas Island are of 2,500 breeding pairs (Menkhorst et al. 2017). The species' restricted geographical location is thought to be attributed to areas of upwelling in the waters surrounding Christmas Island, which may provide prey items that are seasonal and necessary for raising offspring. However, data suggests that individuals may travel up to hundreds of kilometres from Christmas Island in order to forage (DoEE 2018y). Considering the project area is significantly distant from Christmas Island (approximately 2,061 km), it is likely that only a few individuals may utilise the open waters of the project area.

**Greater Frigatebird**

The greater frigatebird (*Fregata minor*; migratory) is widespread and breeds on a number of small and remote tropical and sub-tropical islands (DSEWPaC 2012f; Birdlife International 2017a). Whilst the species typically nests in mangroves or bushes, it may also nest on the bare ground (Birdlife International 2017a). The greater frigatebird forages both inland and along coastlines, potentially straying up to 200 km from the colony to forage during the early breeding season (Birdlife International 2018; DSEWPaC 2012f). The species' diet consists largely of fish, squid and the chicks of other bird species (Birdlife International 2017a; DSEWPaC 2012f).

There are large breeding populations of this species in the tropical waters of the Pacific and Indian Oceans (Birdlife International 2017a). Within WA, the greater frigatebird has a small breeding colony at Ashmore Reef and is found throughout the north and eastern coastal and offshore areas of Australia (DoEE 2018z; DSEWPaC 2012f). The species also breeds on Christmas and North Keeling Islands (Menkhorst et al. 2017). There are BIAs for the greater frigatebird, both breeding and foraging, within the area of influence, as shown in **Figure 6-30**. Considering the species distribution and foraging habits, individuals are likely to utilise the open waters within the project area. Satellite tracking studies undertaken from Ashmore Reef have also shown the species traverses the project area (Mott 2016).

**Lesser Frigatebird**

The lesser frigatebird (*Fregata aerial*; migratory) occurs throughout the tropical and warmer waters of northern and eastern Australia (DSEWPaC 2012f), breeding on islands such as Ashmore Reef and North Keeling, as well as a number of other islands located off the north coast of WA (Menkhorst et al. 2017). There are BIAs for the lesser frigatebird within the area of influence, as shown in **Figure 6-30**. The lesser frigatebird feeds on prey items such as flying fish by catching their prey at or just above the ocean surface (DSEWPaC 2012f). This species also occasionally feeds on squid, octopus and other species chicks, and typically does not forage far from the breeding colony (DSEWPaC 2012f; Birdlife International 2017b).

As with the greater frigatebird, individuals are likely to utilise the open waters within the project area based on the species distribution and feeding preferences. Satellite tracking studies have also shown the species traverses the project area (Mott 2016).

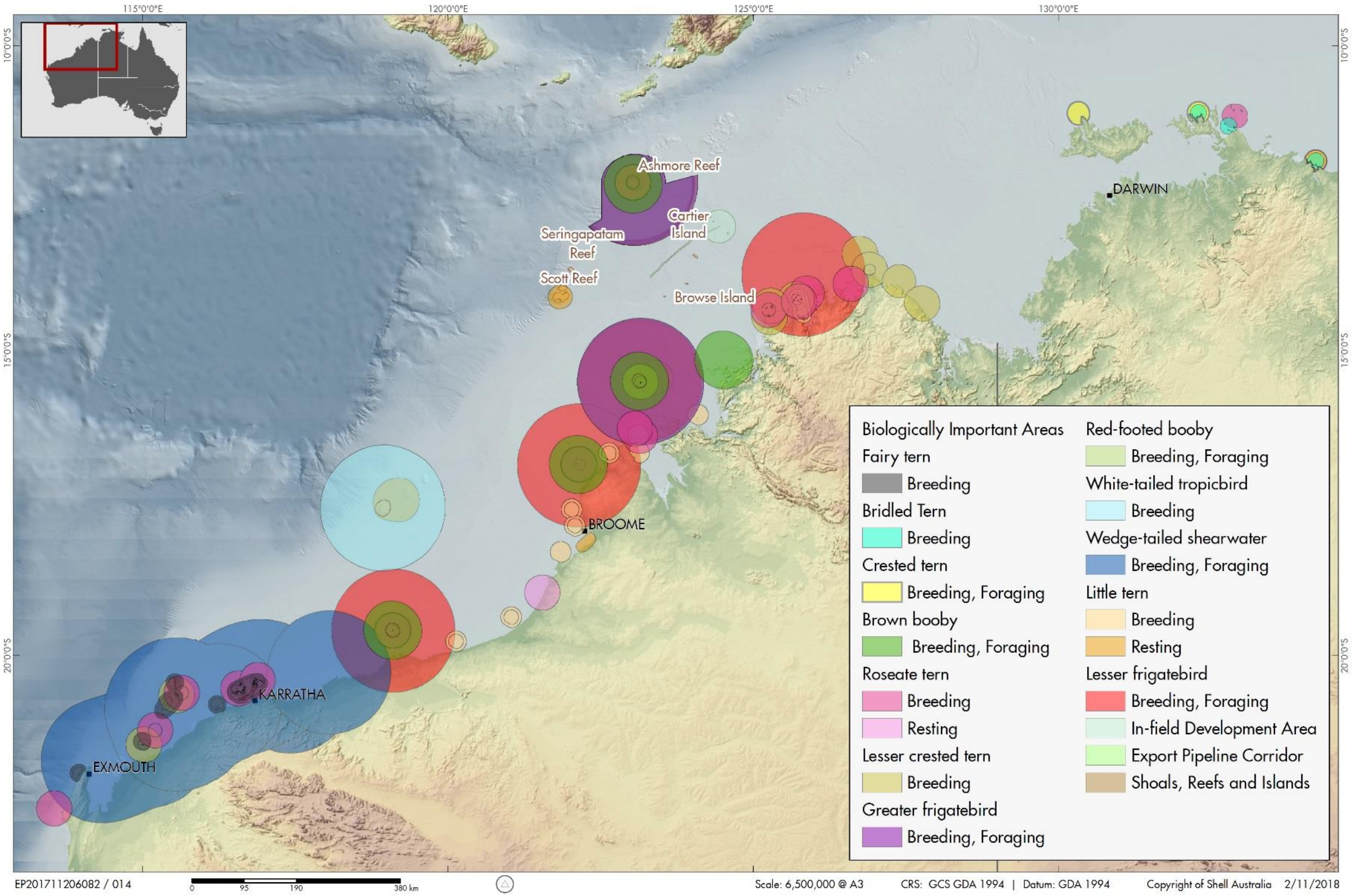



Figure 6-30: Biologically Important Areas for Birds

Table 6-11: Summary of BIAs relevant to Birds within the Area of Influence

| Species | BIAs within the Area of Influence | General Location(s) |
|---|---|---|
| Fairy tern (*Sternula nereis nereis*) | Breeding | WA (Pilbara and Gascoyne) coastline and adjacent offshore islands |
| Roseate tern (*Sterna dougalii*) | Resting | Eighty Mile Beach (northern end) |
| | Breeding | Haul Round Island (Boucat Bay), Grant Island, WA (Kimberley, Pilbara and Gascoyne) coastline and offshore islands (including Ashmore Reef) |
| Lesser crested tern (*Thalasseus bengalensis*) | Breeding | WA (Kimberley, Pilbara and Gascoyne) coastline and offshore islands (including Ashmore Reef). It is noted that expert opinion provided for the Barossa Area Development Project indicated that this is predominantly an inshore species and does not occur at Ashmore Reef of Cartier Islands (ConocoPhillips 2018). |
| White-tailed tropicbird (*Phaethon lepturus*) | | Ashmore Reef, Cartier Island, WA (Kimberley, Pilbara and Gascoyne) coastline and offshore islands (including Cunningham Island and Bedwell Island) |
| Lesser frigatebird (*Fregata ariel*) | Breeding/foraging | Ashmore Reef, Cartier Island, WA (north west Kimberley and Pilbara) coastline |
| Greater frigatebird (*Fregata minor*) | | Ashmore Reef, Cartier Island, WA (north west Kimberley) coastline |
| Red-footed booby (*Sula sula*) | | |
| Wedge-tailed shearwater (*Ardenna pacifica*) | | Ashmore Reef, Cartier Island, WA (Kimberley, Pilbara and Gascoyne) coastline and offshore islands |
| Crested tern (*Thalasseus bergii*) | | Crocodile Islands, north-east of Milingimbi (Large Island), Haul Round Island (Boucat Bay), Cobourg Peninsula (No. 2 Sandy Island), Seagull Island |
| Brown booby (*Sula leucogaster*) | | Kimberley and northern Pilbara coastlines and adjacent islands, Ashmore Reef |
| Little tern (*Sternula albifrons*) | Breeding | WA (Kimberley and Pilbara) coastline |
| | Resting | Ashmore Reef, WA (kimberley, Pilbara and Gascoyne) coastline and offshore islands |

**EPBC Management/Recovery Plans and Conservation Advices**

The EPBC Management/Recovery Plans and conservation advices for the birds identified in the EPBC Protected Matters searches for the project area and area of influence are summarised in **Table 6-12**.

Table 6-12: Summary of EPBC Management/Recovery Plans and Conservation Advices Relevant to Birds

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Sandpipers (includes snipes – excluding the Australian painted snipe, godwits, curlews, whimbrel, redshank, greenshank, sandpiper, tattler, turnstone, dowitcher, knots, sanderling, stints) and plovers listed in **Table 6-6** | Wildlife Conservation Plan for Migratory Shorebirds (DoE 2015e) | Habitat (wetland) loss due to infrastructure/ coastal development | N | The key threats are outside the scope of this OPP |
| | | Anthropogenic disturbance (e.g. aircraft over-flights, industrial operations and construction, artificial lighting, recreational activities such as fishing, four-wheel driving, pets, water craft) | N | |
| | | Climate change and variability | N | |
| | | Harvesting of shorebird prey | N | |
| | | Fisheries by-catch | N | |
| | | Hunting | N | |
| | | Modification habitat (e.g. chronic pollution from herbicides/ pesticides, acute pollution from oil/ chemical spills, invasive species (including introduced plant species, marine pests in intertidal habitats, pigs, cane toads and cats) and altered hydrological regimes) | N | The key threats are outside the scope of this OPP as they relate to disturbances to wetland habitats in coastal areas.<br>Consideration is given to this species in the context of habitat degradation from pollution associated with unplanned waste management (Section8.4.7) and emergency/unplanned events (Section 8.4.9). |
| White-tailed tropicbird | Conservation advice on white-tailed tropicbird (*Phaethon letpurus fulvus*) (October 2014)<br>(DoE 2014b) | Introduced predators and invasive species (e.g. feral cats, black rats, yellow crazy ant) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |
| Round Island petrel | Conservation advice on Round Island petrel (*Pterodroma arminjoniana*) (January 2015)<br>(DoE 2015f) | Introduced predators (potential threat) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |
| | | Disturbance and habitat loss (potential threat from cyclonic weather) | N | The key threat is outside the scope of this OPP |
| Soft-plumaged petrel | Conservation advice on soft-plumaged petrel (*Pterodroma mollis*) (January 2015) (DoE 2015g) | Introduced predators (potential threat) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Black-browed albatross<br>Southern giant-petrel | National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011a) | Marine pollution | Y | Section 8.4.8, Section 8.4.9<br>These species are only relevant with regards to the area of influence |
| | | Fishing (e.g. bycatch, resource competition, dependence on discards) | N | The key threats are outside the scope of this OPP |
| | | Climate change | N | |
| | | Disturbance (human, e.g. deliberate shooting/killing, nest disturbance) | N | |
| | | Habitat loss (e.g. loss of nesting habitat) | N | |
| | | Competition for nesting space | N | |
| | | Introduced predators (e.g. cats, rabbits, rodents) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |
| | | Parasites/disease | N | |
| Australian fairy tern | Conservation advice on fairy tern (*Sternula nereis nereis*) (February 2011) (DSEWPaC 2011b) | Oil spills (main potential threat; particularly in Victoria) | Y | Section 8.4.8, Section 8.4.9<br>Species is only relevant with regards to the area of influence |
| | | Increased salinity in waters adjacent to colonies leading to a reduction in prey abundance | N | The key threats are outside the scope of this OPP |
| | | Disturbance (e.g. humans, dogs, vehicles) | N | The key threats are outside the scope of this OPP as they relate to terrestrial pathways |
| | | Irregular water management (causing flooding of nests or allowing predators access to breeding colonies) | N | |
| | | Weed encroachment (on nest sites) | N | |
| | | Introduced predators (e.g. foxes, dogs, cats, rats, native birds) | N | |
| Australian painted snipe | Conservation advice on Australian painted snipe (*Rostratula australis*) (May 2013) (DoE 2013b) | Habitat (wetland) loss and degradation (e.g. through agricultural development, livestock grazing/trampling of vegetation) | N | The key threats are outside the scope of this OPP |
| | | Human disturbance (e.g. coastal and port | N | |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| | | infrastructure developments) | | |
| | | Shale oil mining (potential threat on the Queensland coast) | N | |
| | | Climate change | N | |
| | | Predation (potential threat e.g. by introduced predators) | N | The key threats are outside the scope of this OPP as they relate to terrestrial pathways |
| | | Invasive species (e.g. weed species) | N | |
| Curlew sandpiper[P]<br>Eastern curlew[P] | Conservation advice on curlew sandpiper (*Calidris ferruginea*) (May 2015)<br>(DoE 2015h)<br><br>Conservation advice on eastern curlew (*Numenius madagascariens-is*) (May 2015)<br>(DoE 2015i) | Ongoing human disturbance (in coastal areas and shoreline habitats) | N | The key threats are outside the scope of this OPP as they relate to disturbances in coastal areas and loss of intertidal mudflat habitat at key migration staging sites in the Yellow Sea.<br>Consideration is given to these species in the context of habitat degradation from pollution associated with unplanned waste management (Section 8.4.7) and emergency/unplanned events (Section 8.4.9). |
| | | Habitat (intertidal mudflats) loss and degradation from pollution | | |
| | | Changes to the water regime and invasive plants (in coastal areas and shoreline habitats) | | |
| Australian lesser noddy[P] | Conservation advice on Australian lesser noddy (*Anous tenuirostris melanops*) (October 2015)<br>(DoE 2015j) | Habitat loss from pollution | Y | Section 8.4.8, Section 8.4.9 |
| | | Habitat loss from catastrophic weather events | N | The key threats are outside the scope of this OPP |
| | | Overfishing | | |
| | | Feral animals | | |
| Red knot[P] | Conservation advice on red knot (*Calidris canutus*) (May 2016) (DoE 2016a) | Pollution/contamination | Y | Section 8.4.8, Section 8.4.9 |
| | | Habitat loss and habitat degradation (e.g. through land reclamation, industrial use and urban expansion, changes to the water/hydrological regime, loss of marine or estuarine vegetation, invasive plants and environmental pollution of foraging and roosting sites) | N | The key threats are outside the scope of this OPP as they relate to disturbances to foraging/roosting sites in coastal areas.<br>Consideration is given to this species in the context of habitat degradation from pollution associated with unplanned waste management (Section 8.4.7) and emergency/unplanned events (Section 8.4.9). |
| | | Climate change | N | The key threats are outside the scope of this OPP |
| | | Diseases | | |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| | | Disturbance (human-related, e.g. from recreational activities including fishing, boating, four-wheel driving, walking dogs, noise and night lighting) | N | These key threats are outside the scope of this OPP as they relate to disturbances from activities that are coastal related or are not directly relevant to the project.<br>Consideration is given to this species in the context of disturbance from night lighting (Section 8.4.2). |
| | | Direct mortality (e.g. wind farms, bird strike with vehicles and aircraft, hunting, chemical spills and oil spills) | N | These key threats are outside the scope of this OPP as they relate to disturbances from activities that are not directly relevant to the project.<br>Consideration is given to this species in the context of disturbance from chemical/ oil spills (Section 8.4.9). |
| Great knot | Conservation advice on great knot (*Calidris tenuirostris*) (May 2016) (DoE 2016b) | Pollution/contaminants | Y | Section 8.4.8, Section 8.4.9 |
| | | Habitat loss and degradation (e.g. through land reclamation, industrial use and urban expansion, changes to the water regime, invasive plants, water quality deterioration and environmental pollution) | N | The EPBC Protected Matters search has not recorded the species within the project area. Some of the key threats are also outside the scope of this OPP.<br>Consideration is given to this species in the context of habitat degradation from pollution associated with unplanned waste management (Section 8.4.7) and emergency/unplanned events (Section 8.4.9). |
| | | Climate change | N | The key threats are outside the scope of this OPP |
| | | Diseases | | |
| | | Direct mortality – hunting | | |
| | | Disturbance (human-related, e.g. from recreational activities including fishing, boating, four-wheel driving, walking dogs, noise and night lighting) | N | These key threats are outside the scope of this OPP as they relate to disturbances from activities that are coastal related or are not directly relevant to the project. |
| Abbott's booby[P] | Conservation advice on Abbott's booby (October 2015) (DoE 2015k) | Loss of rainforest habitat | N | Not applicable – the key threats are outside the scope of this OPP |
| | | Introduced terrestrial species (e.g. yellow crazy ant) | | |
| | | Pollution/contamination | Y | Section 8.4.8, Section 8.4.9 |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Greater sand plover<br>Lesser sand plover | Conservation advice on greater sand plover (*Charadrius leschenaultii*) (May 2016) (DoE 2016c)<br>Conservation advice on Lesser sand plover (*Charadrius mongolus*) (May 2016) (DoE 2016d) | Habitat loss and degradation (e.g. loss of marine or estuarine vegetation, land clearing, intertidal reclamation, changes to the water/ hydrological regime, changes in water quality, hydrology or structural changes near roosting sites, water pollution, and residential, farming, industrial and aquaculture/fishing activities) | N | The EPBC Protected Matters search has not recorded the species within the project area. Some of the key threats are also outside the scope of this OPP.<br>Consideration is given to this species in the context of habitat degradation from pollution associated with unplanned waste management (Section 8.4.7) and emergency/unplanned events (Section 8.4.9). |
| | | Climate change<br>Diseases | N | The key threats are outside the scope of this OPP |
| | | Disturbance (human-related, e.g. from recreational activities including fishing, boating, four-wheel driving, walking dogs, noise and night lighting) | N | These key threats are outside the scope of this OPP as they relate to disturbances from activities that are coastal related or are not directly relevant to the project. |
| | | Introduced species (invasion of intertidal mudflats by terrestrial weeds) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |
| | | Direct mortality (e.g. from collision with large structures (e.g. wind farms) or vehicles/aircraft, commercial hunting and predation) | N | The EPBC Protected Matters search has not recorded the species within the project area. The key threats are also outside the scope of this OPP. |
| Northern Siberian bar-tailed godwit | Conservation advice on bar-tailed godwit (northern Siberian) (*Limosa lapponica menzbieri*) (May 2016) (DoE 2016e) | Pollution/contamination | Y | Section 8.4.8, Section 8.4.9 |
| | | Habitat loss and degradation (e.g. loss of marine or estuarine vegetation, changes to the water/hydrological regime, reduced river flows, intertidal reclamation, environmental pollution, industrial use and urban expansion) | N | The EPBC Protected Matters search has not recorded the species within the project area. Some of the key threats are also outside the scope of this OPP.<br>Consideration is given to this species in the context of habitat degradation from pollution associated with unplanned waste management (Section 8.4.7) and emergency/unplanned events (Section 8.4.9). |
| | | Climate change<br>Diseases | N | The key threats are outside the scope of this OPP |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| | | Disturbance (human-related, e.g. from recreational activities including fishing, boating, four-wheel driving, walking dogs, noise and night lighting) | N | These key threats are outside the scope of this OPP as they relate to disturbances from activities that are coastal related or are not directly relevant to the project. |
| | | Introduced species (invasion of intertidal mudflats by terrestrial weeds) | N | The key threat is outside the scope of this OPP as it relates to terrestrial pathways |
| | | Direct mortality (e.g. from collision with large structures (e.g. wind farms) or vehicles/aircraft, commercial hunting and predation) | N | The EPBC Protected Matters search has not recorded the species within the project area. The key threats are also outside the scope of this OPP. |
| Christmas Island frigatebird | Conservation advice on Christmas Island frigatebird *(Fregata andrewsi)* (DoE 2016f)<br><br>National recovery plan for the Christmas Island Frigatebird (*Fregata andrewsi*) (Hill and Dunn 2004) | Habitat loss, disturbance and modifications (e.g. deforestation (past threat) and phosphate dust) | N | The key threats are outside the scope of this OPP |
| | | Fishing (e.g. mortality from bycatch, poisoning and shooting and starvation due to overfishing of large predatory fish) | | |
| | | Invasive species (e.g. weeds and potential threats due to yellow crazy ants, cats and rats) | | |
| | | Climate change (e.g. increased frequency of severe storms and increased sea surface temperatures) (future threats) | | |

[P] The species was identified as potentially occurring or having habitat in the project area.

#### 6.5.6.4 Fish

The Timor Sea supports a variety of fish species of high conservation value as well as fisheries of commercial and recreational importance. The current state of knowledge of fishing activities within the project area in a socio-economic and indigenous use context is discussed further in **Section 6.6.9** and **Section 6.6.10**.

A search of the EPBC Act Protected Matters database identified 30 fish species that may occur or have habitat in the project area, and 52 species which may occur in the area of influence. These are ray-finned fishes and are either pipefish or seahorses (family

Syngnathidae). All species of Syngnathidae are listed marine species under the EPBC Act. These species may pass through the offshore waters of the project area but are more likely to be associated with the shallow waters around the nearby shoals/banks (**Section 6.4.4**) and close to the WA coastline where benthic communities provide suitable shelter and foraging habitats (DSEWPaC 2012g). Knowledge about the distribution, abundance and ecology of Syngnathidae within the NWMR is limited, however, almost all species live in nearshore and inner shelf habitats, usually in shallow coastal waters (DSEWPaC 2012g).

**Fish Communities at Shoals**

Fish communities found at the submerged shoals within the area of influence are described in **Section 6.4.4**. In summary, the pelagic biota of the shoals were found to be similar to those on coral reefs and biologically rich. Of the species recorded, 97% were teleost fish with the remainder consisting predominantly of sharks and rays.

#### 6.5.6.5 Sharks and Rays

The NWMR has a rich fauna of sharks and rays due to the diverse marine habitats within the region's waters (DSEWPaC 2012h). A search of the EPBC Act Protected Matters database identified twelve listed threatened and/or migratory shark and ray species that may occur in or have habitat in the area of influence. Listed threatened shark and ray species (five of which are also listed as migratory) were the great white shark (*Carcharodon carcharias;* vulnerable), speartooth shark (*Glyphis glyphis*; critically endangered), northern river shark (*Glyphis garricki*; endangered), green sawfish (*Pristis zijsron*; vulnerable), largetooth sawfish (*Pristis pristis*; vulnerable) and dwarf sawfish (*Pristis clavata*; vulnerable).

The listed migratory species of shark and rays that may occur within the area of influence include the narrow sawfish (*Anoxypristis cuspidata*), longfin mako (*Isurus paucus*), shortfin mako (*Isurus oxyrinchus*), reef manta ray (*Manta alfredi*) and giant manta ray (*Manta birostris*).

**Whale Shark**

The whale shark (*Rhincodon typus*; vulnerable) is globally distributed in tropical and warm temperate waters, and it is thought individuals form one single genetic population (DoE 2015l). Key areas of concentration within Australian waters include the Ningaloo coast (March – July), Christmas Island (December – January) and the Coral Sea (November – December), with the timing of the aggregations thought to be linked to seasonal fluctuations in prey abundance (DoE 2015l). The species is an epipelagic filter feeder; therefore, their diet typically consists of planktonic and nektonic species, including small crustaceans and smaller schooling fish species (DoEE 2018aa; DoE 2015l).

Whale sharks are known to be highly migratory with migrations of 13,000 km being recorded (Eckert and Stewart 2001). Migration along the northern WA coastline broadly follows the 200 m isobath and typically occurs between July and November (DoE 2015l).

A biologically important area for whale sharks is located in northern WA, offshore of the Pilbara and Kimberley coastline, and broadly follows the 200 m isobath (**Figure 6-31**; DoEE 2018aa). The BIA is listed as a foraging habitat, however the Conservation Advice (DoE 2015l) for this species indicates this BIA up the north west coast is a migration corridor than significant foraging habitat. This is consistent with tagging studies; Meekan and Radford (2010) showed that whale sharks migrated up the coast from Ningaloo Reef and dispersed individually over a broad migratory area either north-west into the open Indian Ocean, northward towards Sumatra and Java, or north-east towards the Timor Sea. The project area and area of influence intersect a portion of this BIA. Therefore, whale sharks are expected to transit through the project area as part of their broad migratory movement.

**Great White Shark**

The great white shark (*Carcharodon carcharias*; vulnerable) was identified by the EPBC Protected Matters database search as potentially occurring within the project area. The species is primarily temperate, however, there are no known aggregation sites within the NWMR and the species is most likely to be found south of North West Cape (some 1,400 km south-southwest of the project area) (DSEWPaC 2012h). Ongoing research into the seasonal movements of this species along the WA coast suggests great white sharks travel northward during spring, returning to more southern waters in summer (DoEE 2018ab). Little information is available on reproductive activities of great white sharks in Australian waters, with no pupping grounds having been identified (DSEWPaC 2012h).

Due to their relatively wide ranging and migratory behaviour along the WA coast, it is likely that great white sharks may transit the project area.

**Mako**

The shortfin mako (*Isurus oxyrinchus*; migratory) and longfin mako (*Isurus paucus*; migratory) were identified by the EPBC Protected Matters database search as potentially occurring in the project area and area of influence. The shortfin mako is a highly migratory epipelagic species widely distributed in tropical and temperate waters of temperatures above 16 °C (Groeneveld et al. 2014). The distribution and biology of the longfin mako is less well documented, however, it is also an epipelagic shark inhabiting tropical and warm-temperature waters (Reardon et al. 2006). Makos exhibit sexual and developmental segregation; juveniles spend 90% of their time near the surface whereas adults dive much deeper (Groeneveld et al. 2014).

There are no known BIAs for the shortfin or longfin mako within the area if influence. Due to their migratory nature and known species distribution it is possible that these species may transit the project area.

**Sawfish**

The listed threatened (vulnerable) dwarf sawfish (*Pristis clavata*), green sawfish (*Pristis zijsron*) and largetooth sawfish (*Pristis pristis*) occur mainly in inshore coastal waters and riverine environments in northern Australia. Considering declining global populations of these sawfishes, northern and north-west Australia may contain the last significant populations of these species (DSEWPaC 2012h).

The dwarf sawfish is primarily a coastal and estuarine species and juveniles appear to remain in estuarine waters only. Individuals have been shown to show site fidelity and maintain a coastal fringe of just a few square kilometres (DSEWPaC 2012h). The largetooth sawfish has been recorded in river, estuarine and marine environments within north-west Australia. Newborns and juveniles occur primarily in the freshwater areas of rivers and in estuaries, while adults mostly occupy marine and estuarine environments (DSEWPaC 2012h). The green sawfish does not occupy freshwater habitats and has been recorded in depths of up to 70 m. However, it is predominately recorded as occurring in inshore coastal areas, including estuaries and river mouths (DSEWPaC 2012h). It is therefore unlikely that these species of sawfish will transit the project area. There are BIAs for all three sawfish species along the WA coastline within the area of influence, as shown in **Figure 6-31**.

**Rays**

The giant manta ray (*Manta birostris;* migratory) and reef manta ray (*Manta alfredi*; migratory) are globally distributed in both tropical and temperate waters. Whilst considered the more solitary of the two species, the giant manta ray is often sighted in high numbers to engage in foraging, mating or cleaning activities (Marshall et al. 2011a). The giant manta ray also exhibits seasonality in habitat preference and is known to frequent offshore seamounts and islands, including the Cocos Islands (Marshall et al. 2011a). The giant manta ray is less frequently sighted than the reef manta ray (Marshall et al. 2011a).

The reef manta ray typically utilises productive nearshore habitats, including island groups, atolls and continental coastlines (Marshall et al. 2011b). However, the species has been known to undertake coastal migrations of significant distances and traverse international waters. As with the giant manta ray, this species is often sighted in high numbers, predominately when undertaking foraging activities as a group or migrating.

There are no known foraging or breeding aggregation areas for these species within the project area. Based on the nearshore habitat preference of both the giant manta ray and reef manta ray, and the offshore location of the project area, it is considered highly unlikely that they will occur in significant numbers in this area. If present, they would most likely be restricted to individuals transiting through the area.

**Speartooth Shark and Northern River Shark**

Sharks of the genus *Glyphis* are considered among the most threatened elasmobranchs worldwide and appear to have limited habitat preferences (Stevens et al. 2005). The speartooth shark (*Glyphis glyphis;* critically endangered) has been recorded as occurring in riverine and marine environments, and juveniles and sub-adults reportedly utilise large tropical river systems as their primary habitat (Stevens et al. 2005; DSEWPaC 2010c). It is thought that their marine distribution may be limited to the coastal marine environment outside of rivers, much like that of the bull shark (DSEWPaC 2010c). Northern river sharks (*Glyphis garricki;* endangered) also exhibit segregation during developmental stages and similarly occupy rivers, tidal sections, large tropical estuarine systems, macrotidal embayments, inshore and offshore marine habitats (DSEWPaC 2010d). The northern river shark has been recorded in offshore waters, however, the frequency of this occurrence is unknown.

Within WA speartooth sharks are known to occur historically in the Cambridge Gulf, however, remaining populations (throughout Australia) are considered isolated and their viability is therefore questionable. The northern river shark has a wider known distribution including locations in the west and east Kimberley (DSEWPaC 2010c; 2010d). Both species were listed threatened in 2001 due to their limited geographical distribution and low population estimates of mature individuals which was considered likely to continue to decline (DSEWPaC 2010c; 2010d). Given their typically limited distribution in proximity to estuarine environments, neither species are expected to transit the project area.

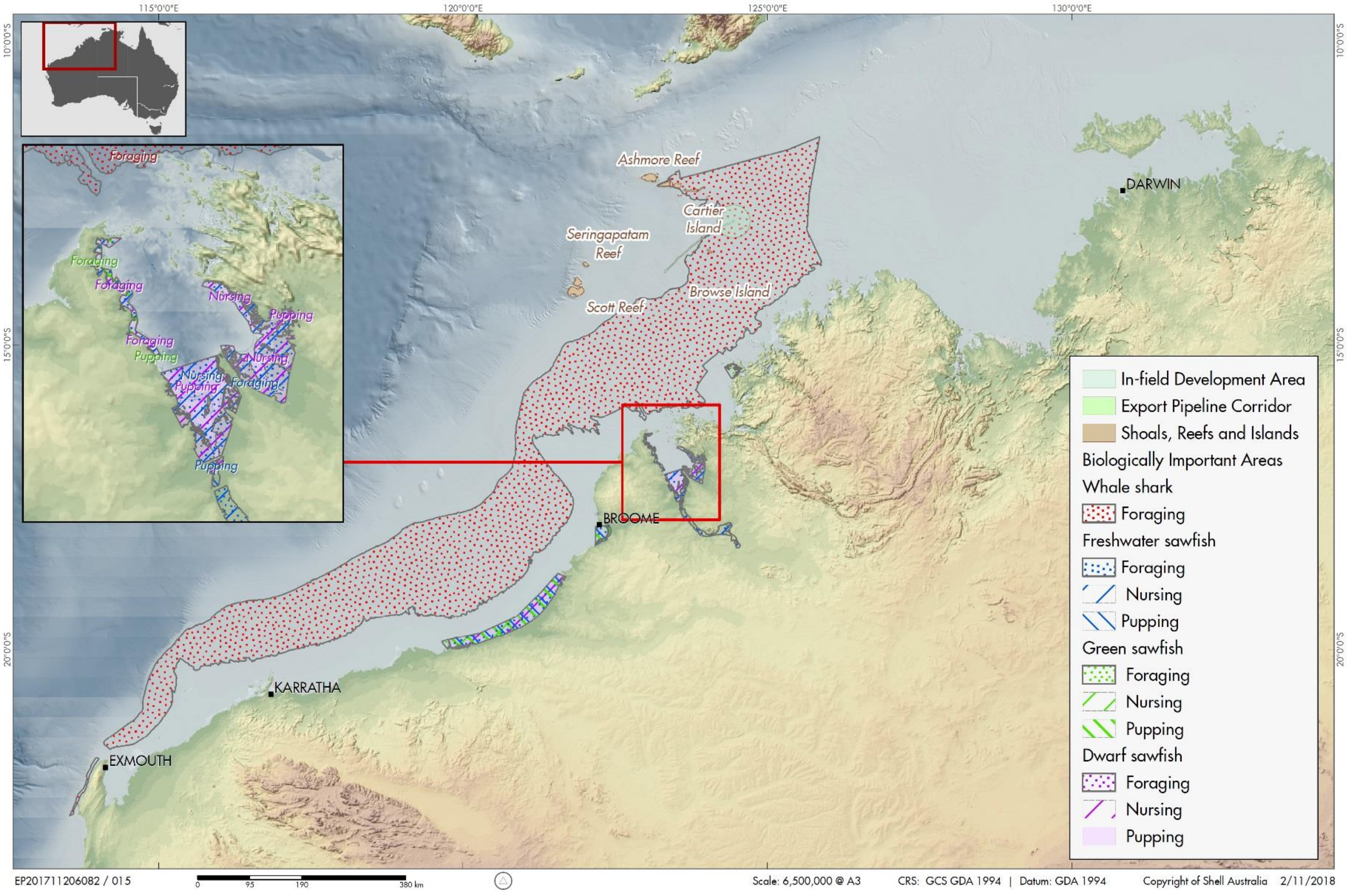



Figure 6-31: Biologically Important Areas for Sharks and Rays

**EPBC Management/Recovery Plans and Conservation Advices**

The EPBC Management/Recovery Plans and conservation advices for the shark and ray species identified in the EPBC Protected Matters searches for the project area and area of influence are summarised in **Table 6-13**.

Table 6-13: Summary of EPBC Management/Recovery Plans and Conservation Advices Relevant to Sharks and Rays

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Whale shark[P] | Whale shark (*Rhincodon typus*) Recovery Plan (2005) (May 2005) (DEH 2005a)<br><br>Conservation advice on whale shark (*Rhincodon typus*) (October 2015) (DoE 2015l) | Habitat disruption from mineral exploration, production and transportation | Y | Section 8.4.1 |
| | | Vessel strike | Y | Section 8.4.1 |
| | | Pollution and marine debris | Y | Section 8.4.7, Section 8.4.8 |
| | | Intentional/ unintentional mortality from fishing outside of Australian waters (principle threat) | N | The key threats are outside the scope of this OPP |
| | | Climate change | | |
| | | Disturbance from tourism operations | | |
| Great white shark[P] | Recovery Plan for the White Shark (*Carcharodon carcharias*) (August 2013) (DSEWPaC 2013c) | Habitat modification/ degradation (e.g. development, pollution)<br>(note, coastal habitat degradation and anthropogenic activities in near-coast areas are of primary relevance as they are often a preferred habitat) | Y | Section 8.4.1, Section 8.4.7, Section 8.4.8, Section 8.4.9 |
| | | Accidental (bycatch) or illegal (targeted) capture by commercial and recreational fisheries (including issues of post release mortality) | N | The key threats are outside the scope of this OPP |
| | | Shark control activities (e.g. beach meshing or drum lining) | | |
| | | Illegal trade | | |
| | | Climate change | | |
| | | Ecotourism | | |

| Species | EPBC Management Plan/Recovery Plan/ Conservation Advice | Key Threats Identified in relevant Management Plan/ Recovery Plan/ Conservation Advice | Relevant? | Cross-reference to OPP Impact and Risk Evaluation |
|---|---|---|---|---|
| Speartooth shark<br>Northern river shark[P]<br>Green sawfish[P]<br>Largetooth sawfish[P]<br>Dwarf sawfish | Sawfish and River Sharks Multispecies Recovery Plan (November 2015)<br>(DoE 2015m)<br><br>Conservation advice on speartooth shark (*Glyphis glyphis*) (April 2014) (DoE 2014c),<br>northern river shark (*Glyphis garricki*) (April 2014) (DoE 2014d),<br>dwarf sawfish (*Pristis clavata*) (October 2009)<br>(DEWHA 2009b)<br>and green sawfish (*Pristis zijsron*) (2008) (DEWHA 2008b) | Habitat degradation and modification<br>(note, the recovery plan focusses on river and estuarine barriers that affect the migration of river sharks/sawfish) | Y | Section 8.4.1, Section 8.4.7, Section 8.4.8, Section 8.4.9 |
| | | Marine debris (potential threat) | Y | Section 8.4.7 |
| | | Fishing activities including being caught as by-catch and illegal, unreported and unregulated fishing (principle threat) | N | The key threats are outside the scope of this OPP |
| | | Collection for display in public aquaria (potential threat) | | |

[P] The species was identified as potentially occurring or having habitat in the project area.

## 6.6 Socio-economic and Cultural Environment

The primary focus for the socio-economic and cultural setting of the Crux project is the existing marine users and interests relevant to the offshore context of the NNM platform and supporting infrastructure in Commonwealth marine waters, reflecting the scope of this OPP. Given the remote distance of the proposed Crux platform (approximately 190 km offshore north-west Australia and 620 km north-north-east of Broome), there are limited socio-economic interactions, expected to be primarily related to other marine users (specifically other marine traffic, oil and gas facilities and commercial fishing).

In the future operations phase, it is expected that the Crux project will utilise the onshore facilities (Broome and Darwin) used to service the Prelude FLNG facility, and leveraging the established supply chain, logistics and community partnerships that have been embraced by Shell and its supply chain partners to date. Specifically, Crux will use the same logistics arrangements as the Prelude FLNG facility, to take advantage of existing infrastructure, such as infield support vessels and helicopters. As for the Prelude FLNG facility, it is expected people movements will occur through fixed wing commercial flights to Broome and then rotary wing transport to field, with helicopter re-fuelling stops as required at the Djarindjin Airport. For marine movements, it is envisaged the supply chain will mainly operate through the existing Shell supply base in Darwin, utilising the platform support vessel or other vessels as required. While the onshore support facilities are not specifically within the scope of this OPP, an overview of the existing socio-economic environment of the communities of Broome and Darwin are provided for context and consistent with Shell's internal impact assessment requirements.

Local content is a core element of Shell's operations, and is prioritised alongside safety, environment, performance and cost.

### 6.6.1 Kimberley Region

The Kimberley region is remote from metropolitan areas, with the major towns of Broome being 2,213 km and Kununurra being 3,205 km from Perth by road. Other major towns include Derby, Halls Creek, Wyndham and Fitzroy Crossing. Throughout the region there are over 100 Aboriginal communities of varying population sizes.

The most populous local government area in the Kimberley region is the Shire of Broome, with approximately 43% of the regional population (Department of Regional Development 2014).

Broome is also the regional employment hub and a significant centre for servicing and growing the region's industries.

The Kimberley is renowned to be rich in both natural and cultural assets and enjoys a broad-based and diverse economy (Kimberley Development Commission 2015). With a geographic area in excess of 420,000 square kilometres, equivalent to one-sixth of WA, the Kimberley has a population of 34,364 (Australian Bureau of Statistics (ABS) 2016a), with the principal towns of Broome and Kununurra having populations of 16,222 and 5,308, respectively (ABS 2016b; 2016c). As noted above, the main interaction with regional onshore communities will be limited to Broome and community of Djarindjin-Lombadina.

The Broome international airport is the largest airport in the region and will be the primary flight centre to be used for workforce to/from the Crux project when transiting through Broome. In line with our social performance policies and our commitments to acting as a good neighbour, Shell continually engages with stakeholders in Broome and Djarindjin-Lombadina and has in place existing grievance and community feedback mechanisms to facilitate community engagement.

### 6.6.2 Darwin

Darwin is the capital city of the NT and is located approximately 700 km to the east of the Crux platform and approximately 1,100 km north east of Broome.

Darwin has an established industrial and commercial centre and is serviced by the Darwin Port. Darwin Port's facilities predominantly serve shipping and cargo markets for livestock exports, dry bulk imports and exports, container and general cargo, cruise and naval vessels, petroleum and other bulk liquids and offshore oil and gas rig services (Darwin Port 2015). The Onshore Darwin Supply Base for the Prelude FLNG facility is located at East Arm Port in Darwin and is proposed to be used in support of the Crux project. Commercial and recreational fishing industries are both represented in Darwin, operating in Darwin Harbour (recreational only) and offshore.

### 6.6.3 Commonwealth Marine Area and Land

#### 6.6.3.1 Commonwealth Marine Area

The Crux project is located within the Commonwealth marine area, which includes *"any part of the sea, including the waters, seabed and airspace, within Australia's exclusive economic zone and/or over the continental shelf of Australia, that is not state or NT waters. The Commonwealth marine area stretches from three to 200 nm from the coast"* (DoEE 2018aj).

#### 6.6.3.2 Commonwealth Land

Commonwealth land includes land owned or leased by the Commonwealth or a Commonwealth agency, land in the external territories, and any other area of land that is included in a Commonwealth reserve (DSEWPaC 2013d).

Given the remote offshore location context of this proposal within Commonwealth waters, the consideration of Commonwealth land is only of relevance to this OPP in the context of Australia's external territories; Ashmore Reef, Christmas Island and Cocos (Keeling) Islands. These features are only relevant in the context of the area of influence and are discussed in detail in **Section 6.4.5**.

### 6.6.4 World Heritage Properties

There are no World Heritage properties in, or in the immediate surrounds of, the project area. Kakadu National Park, which is approximately 800 km to the east of the Crux platform, is a World Heritage Property relevant only in the context of the area of influence (**Figure 6-32**).

Kakadu National Park encompasses an area 19,804 km$^2$ and was made a World Heritage Property due to its outstanding natural and cultural values (DoEE 2018ac). The National Park has been cared for by generations of Aboriginal people known as Bininj/Mungguy and boasts rock art documenting one of the longest historical records of any group of people in the world. The National Park is also known as a biodiversity hotspot with a number of rare species of birds, mammals, reptiles and plants (DoEE 2018ac). While the majority of the National Park encompasses the NT mainland, the site also includes the mangrove-fringed coast from Wildman River to East Alligator River and offshore islands of Barron Island and Field Island in the Van Diemen Gulf (DoEE 2018ac).

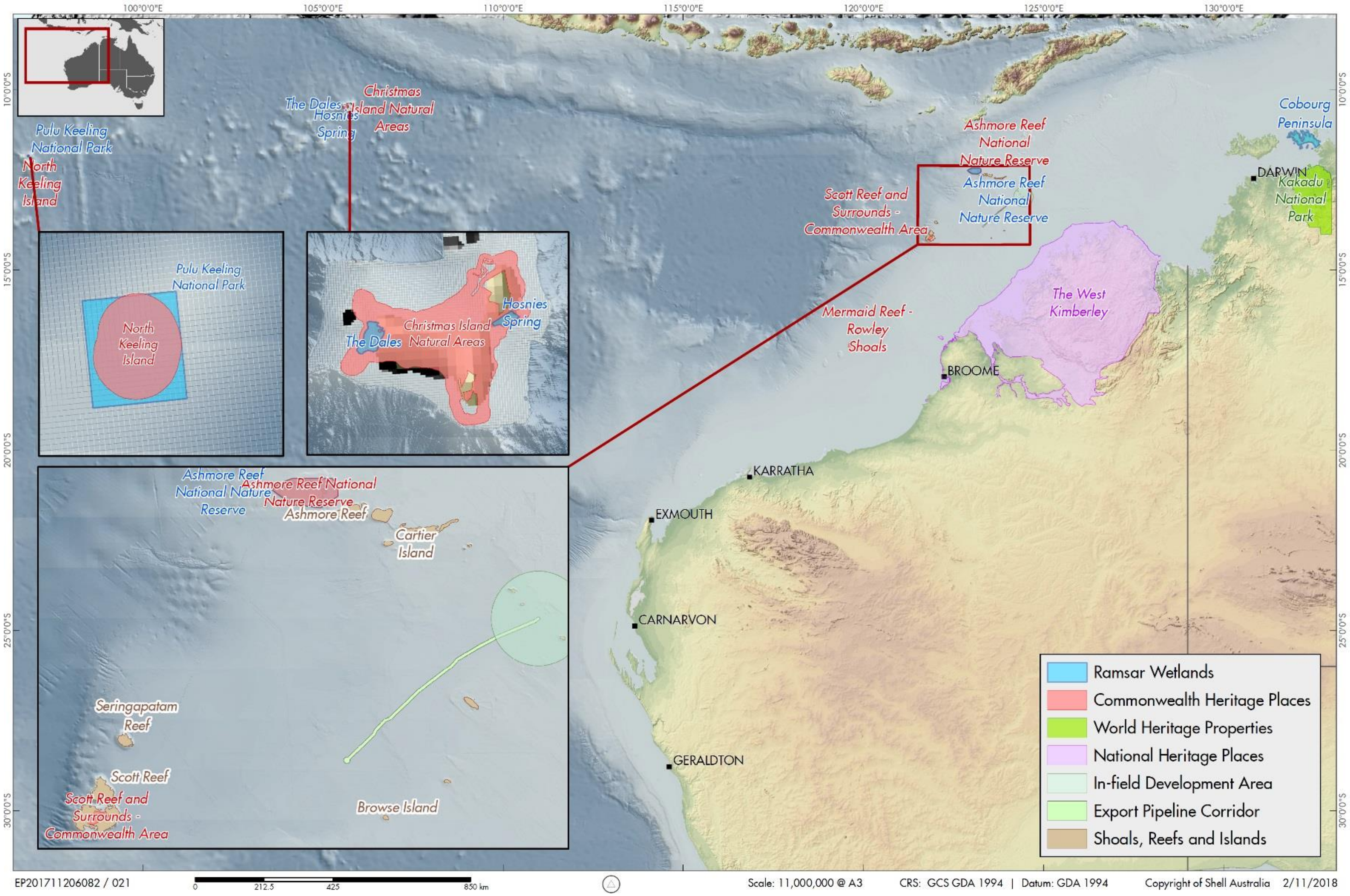



Figure 6-32: Heritage Properties, Places and Ramsar Wetlands

### 6.6.5 National Heritage Places

The National Heritage List is Australia's list of natural, historic and Indigenous places of outstanding significance to the nation. There are no National Heritage properties in, or in the immediate surrounds of, the project area. Within the area of influence, the West Kimberley National Heritage Place is listed as a National Heritage Place and is located approximately 170 km from the Crux platform.

The West Kimberley is known for its ancient geology, Aboriginal culture, stunning landscapes, and biological richness (DoEE 2018ad). The West Kimberley coastline includes a range of landforms, including cliffs, rocky headlands, sandy beaches, rivers, waterfalls and numerous islands located off the coast. The West Kimberley holds extensive history of Aboriginal people who have lived in the area for at least 40,000 years. The West Kimberley also provides remnant habitats for many native animals and plants which are now absent elsewhere in Australia (DoEE 2018ad).

### 6.6.6 Commonwealth Heritage Places

The Commonwealth Heritage List is a list of Indigenous, historic and natural heritage places owned or controlled by the Australian Government. The project is not located in, or in the immediate surrounds of, any Commonwealth Heritage places. There are a number of Commonwealth Heritage Places within the area of influence. These are listed in **Table 6-14**, with a supporting summary of their key values as Commonwealth Heritage Places.

Table 6-14: Commonwealth Heritage Places within the Project Area of Influence

| Commonwealth Heritage Place | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| Ashmore Reef National Nature Reserve | 149 | The Ashmore Reef National Nature Reserve protects Ashmore Reef, a large platform reef with coral reefs, sand flats and three vegetated islands (DoEE 2018ae; see also **Section 6.4.5**). Specific values of this site include:<br>• breeding and foraging habitat for marine turtles<br>• considered to have the world's greatest abundance and diversity of sea snakes<br>• habitat for 569 species of fish, 255 species of corals and 433 species of mollusc, as well as species not previously recorded or rarely recorded in Australia<br>• an important seabird rookery and provides an important staging/feeding area for many seabirds and migratory shorebirds (Environment Australia 2002), and<br>• breeding and feeding habitat for a small dugong population (< 50 individuals) (DoEE 2018ae) |
| Scott Reef and surrounds | 291 | Scott Reef (see also **Section 6.4.5**) is considered regionally important for the following features:<br>• high diversity of marine fauna, including corals, fish and marine invertebrates<br>• physical characteristics of the reefs create environmental conditions which are rare for shelf atolls, including clear deep oceanic water and large tidal ranges that provide a high physical energy input to the marine ecosystem<br>• high representation of species not found in coastal waters off WA and for the unusual nature of their fauna which has affinities with the oceanic reef habitats of the Indo-West Pacific, as well as the reefs of the Indonesian region, and<br>• important for scientific research and benchmark studies into long term geomorphological and reef formation processes due to the age of the reef and the |

| Commonwealth Heritage Place | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | documentation of its geophysical and physical environmental characteristics (DoEE 2018af) |
| Mermaid Reef – Rowley Shoals | 688 | Mermaid Reef (see also **Section 6.4.5**) is one of three reef systems, located 30 – 40 km apart, which make up the Rowley Shoals. The shoal consists of a reef flat roughly 500 to 800 m wide, shallow back reefs and a large lagoon.<br>The Rowley Shoals have been described as the most perfectly formed shelf atolls in Australian waters, and the clear, deep water and large tidal range of the atolls are considered rare environmental conditions for shoals (DoEE 2018ag).<br>The specific values of Mermaid Reef include:<br>• high diversity of marine reef fauna, including corals, fish and marine invertebrates (DoEE 2018ah)<br>• important area for sharks, marine turtles and toothed whales, dolphins, tuna and billfish<br>• important resting and feeding site for migratory seabirds (DoEE 2018ah)<br>• regionally significant due to the presence of many species not found in inshore tropical waters of Northern Australia, and species that are close to their geographical ranges (DoEE 2018ah; DoEE 2018ag). Includes 216 species of fish, 39 species of mollusc and seven species of echinoderms (DoEE 2018ag), and<br>• considered a genetic stepping stone between the Indonesian archipelago and reefs to the south (DoEE 2018ag). |
| North Keeling Island | 3,000 | The North Keeling Island forms the northern atoll of the Cocos (Keeling) Islands (see also **Section 6.4.5**). The island is significant as it is:<br>• one of the remaining pristine islands in the Indian Ocean<br>• the only seabird rookery within 900 km<br>• home to rare species including robber crabs and the buff banded rail, and<br>• important habitat for crabs, and provides nesting area for marine turtles and the red footed booby (DoEE 2018ae). |
| Christmas Island Natural Areas | 2,060 | This 1,220 km$^2$ listing includes the entirety of Christmas Island (see also **Section 6.4.5**). The site has the following values:<br>• a unique ecosystem which makes the study of species evolution in relative isolation possible, as well as the study of adaptions of migrant species to new habitats<br>• a diverse range of land crabs<br>• globally significant seabird island with regards to both diversity and abundance, and<br>• unique relict populations of black-mangrove species and cycads, including a globally significant wetland (DoEE 2018ae). |

### 6.6.7 Declared Ramsar Wetlands

There are no "Wetlands of International Importance" under the Convention on Wetlands of International Importance (Ramsar 1975) in, or in the immediate surrounds of, the project area. The area of influence, however, encompasses a number of Ramsar Wetlands. A summary of the values relevant to each Ramsar site is provided in **Table 6-15**.

Table 6-15: Ramsar Wetlands within the Project Area of Influence

| Ramsar Wetland | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| Ashmore Reef National Nature Reserve (now part of Ashmore Reef Marine Park) | 149 | The Ashmore Reef Marine Park, also a KEF (see **Section 6.4.7**), was designated a Ramsar site primarily due to its importance in supporting large seabird breeding colonies and as a resting place for migratory shorebirds. The boundary of the Ramsar site coincides with the Marine Park (Hale and Butcher 2013). Notably, Ashmore Reef has been managed for conservation purposes for more than 30 years.<br>The five wetland types that have been identified within this Ramsar site are permanent shallow marine waters, sand, shingle or pebble shores, marine subtidal aquatic beds, coral reefs, and intertidal mud, sand or salt flats. Each of these wetland types are in near natural condition and have been recorded as having low densities of coral predators and disease (Hale and Butcher 2013).<br>The three islands of the Ramsar site are the only vegetated islands in the Timor Province bioregion.<br>At the time of listing, this Ramsar site boasted 62 threatened species, including 42 coral, five sea cucumber, eight fish, six reptile and one mammal species. Historically, the site was also significant with regards to sea snake abundance and diversity. The site supports breeding and/or foraging areas for green, loggerhead and hawksbill turtles, and breeding areas for dugongs (Hale and Butcher 2013).<br>The site has been identified as hotspot of biological diversity within the Timor province bioregion, and broader NWMR. |
| Cobourg Peninsula | 817 | The Cobourg Peninsula Ramsar site is located in the NT, approximately 163 km north-east of Darwin. The site was the first Ramsar Wetland in the world, designated for its diversity of coastal and inland wetland habitats, support for populations of endangered species and life-cycle functions (BMT WBM 2011).<br>Wetland types include coral reefs, rocky marine shores, intertidal mud, sand or salt flats, karst, and intertidal marshes. Notably, the majority of the site is terrestrial land, with large areas of Eucalypt-dominated woodlands, and does not support wetland habitat (BMT WBM 2011).<br>Whilst the site contains no towns or settlements the area has been inhabited continuously for at least 50,000 years, and therefore has significant cultural characteristics. |
| “The Dales” Christmas Island | 2,074 | The Dales Ramsar site refers to a system of seven watercourses within the Christmas Island National Park (Butcher and Hale 2010). Three of The Dales support permanent streams and four support intermittent streams. These are predominately surrounded by semi-deciduous forest and a range of karst features typical of Christmas Island (Butcher and Hale 2010).<br>The Ramsar site boasts nine wetland types, including coral reefs, karst and other subterranean hydrological systems, and freshwater, tree-dominated wetlands (Butcher and Hale 2010). The site features many endemic and rare species of plants and animals. The Dales features habitats which support roosting and breeding habitat for seabirds and migratory birds, including populations of the endangered Abbott’s Booby and vulnerable Christmas Island frigatebird (Butcher and Hale 2010). |
| Hosnies Spring Christmas Island | 2,060 | The Hosnies Spring Ramsar site refers to a freshwater spring which surrounds terrestrial vegetation and a small portion of coast within the Christmas Island National Park (Hale and Butcher 2010). The Ramsar site was expanded from |

| Ramsar Wetland | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | approximately 0.3 ha to 202 ha in 2010 in order to provide greater protection for unique freshwater mangrove stand estimated to be 120,000 years old. These mangroves occur at an elevation which has not been recorded elsewhere in the world (Hale and Butcher 2010).<br>The site features a permanent, shallow freshwater wetland fed by a natural spring system, surrounded predominately by rainforest. This is one of the few permanent freshwater features on Christmas Island.<br>Three wetland types have been identified in the Hosnies Spring Ramsar site; permanent rivers/streams/creeks, freshwater, tree dominated wetlands, and freshwater springs; oases (Hale and Butcher 2010).<br>The site also encompasses shallow coral reefs and supports a number of crab, wetland and terrestrial bird species (Hale and Butcher 2010). |
| Pulu Keeling National Park | 3,002 | Pulu Keeling National Park Ramsar site is comprised of the uninhabited North Keeling Island, the northernmost island in the Cocos Islands atoll. The Ramsar site boundary coincides with the Pulu Keeling National Park (Hale 2010).<br>The site comprises approximately 122 ha of land above the high water mark and 2,480 ha of surrounding coral reef and sea (Hale 2010). The four main wetland types identified within the site are marine subtidal aquatic beds, coral reefs, rocky marine shores, and sand, shingle or pebble shores.<br>The site supports a number of seabirds including large breeding colonies of the EPBC listed red-footed booby and lesser frigatebirds, and resident populations of the endangered buff-banded rail (Hale 2010; DoEE 2018ai). Fish fauna within the Ramsar site are considered unique due to the mixing and hybridisation of species from the Cocos (Keeling) Islands and Christmas Island, many of which are at their geographical limits at this location (Hale 2010). |

### 6.6.8 Marine Parks

A search of the EPBC Protected Matters Database confirmed that the project area does not overlap with any Australian Marine Parks (AMPs). However, there are a number of AMPs within the area of influence (refer **Figure 6-33**). In addition, there are a number of State/Territory Marine Parks/Management Areas that are within the area of influence (refer **Figure 6-34**). These Marine Parks/Management Areas are described in **Table 6-16**.

Table 6-16: Marine Parks and Management Areas within the Project Area of Influence

| Marine Park | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| *AMPs – NWMR* | | |
| Argo-Rowley Terrace | 460 | The 146,099 km$^2$ Argo Rowley Terrace Marine Park comprises 83,379 km$^2$ of Multiple Use Zone (IUCN Category VI) and 62,720 km$^2$ of Marine National Park Zone (IUCN Category II). The depth ranges between 220 m and 6,000 m. It is important for foraging areas for migratory seabirds and the endangered loggerhead turtle as well as sharks. It provides connectivity between the Mermaid Reef Marine Park. The area includes canyons linking the Argo Abyssal Plain with |

| Marine Park | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | the Scott Plateau, which is a unique seafloor feature with enhanced productivity and feeding aggregations of species (DoEE 2018ak). |
| Ashmore Reef | 150 | The 583 $km^2$ Ashmore Reef Marine Park comprises a Sanctuary Zone (IUCN category Ia) and a Recreational Use Zone (IUCN category II). It provides an important area for a number of EPBC listed species, including sea snakes, marine turtles, dugongs and migratory seabirds. Ashmore Reef also supports important cultural and heritage sites, such as Indonesian artefacts and grave sites. In 2003, the Ashmore Reef Marine Park was declared a Ramsar Wetland of International Importance due to its conservation values (refer to **Section 6.6.7** for further information) (DoEE 2018al). |
| Cartier Island | 100 | The Cartier Island Marine Park covers a reasonably small area (172 $km^2$) and is comprised of a Sanctuary Zone (IUCN category Ia). The Marine Park provides an important area for a number of EPBC listed species, including sea snakes, turtles and migratory seabirds. Additionally, it supports some of the most important seabird rookeries on the NWS (DoEE 2018am). |
| Dampier | 1,100 | The Dampier Marine Park comprises an area of 1,252 $km^2$, with a Marine National Park Zone (IUCN Category II) and a Habitat Protection Zone (IUCN Category IV). Conservation values for the Marine Park include important staging areas for migratory seabirds, and nesting and foraging areas for marine turtles. It also contains an important migratory pathway for the humpback whale. It also provides a high level of protection for offshore shelf habitats adjacent to the Dampier Archipelago and for the shallow shelf with a depth range of 15 m–70 m (DoEE 2018an). |
| Eighty Mile Beach | 707 | Eighty Mile Beach Marine Park comprises a 10,785 $km^2$ Multiple Use Zone. It contains major foraging areas for migratory seabirds, marine turtles, and part of the migratory pathway for humpback whales. It also contains important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish. The Marine Park provides protection for the shelf with depths ranging from 15 m to 70 m (DoEE 2018ao). |
| Gascoyne | 1,424 | The Gascoyne Marine Park encompasses an area of 81,766 $km^2$ and is comprised of a Multiple Use Zone (IUCN Category VI), Habitat Protection Zone (IUCN Category IV) and Marine National Park Zone (IUCN Category II). The reserve provides protection to many seafloor features and to sponge gardens, as well as providing important foraging areas for seabirds, marine turtles and the whale shark. The reserve also provides a corridor of connectivity from shallow depths of approximately 15 m to deep offshore waters on the abyssal plain at more than 5,000 m depth (DoEE 2018ap). |
| Kimberley | 95 | The 74,469 $km^2$ Kimberley Marine Park is comprised of a National Park Zone (IUCN category II), Habitat Protection Zone (IUCN category IV, specifically intended to protect humpback whale calving) and Multiple Use Zone (IUCN category VI).<br>The marine parks numerous conservation values include the provision of important foraging areas for migratory seabirds, dugongs, dolphins, marine turtles and a migration pathway and nursery areas for humpback whales. The Marine Park also lies adjacent to important foraging and pupping areas for sawfish and important nesting sites for green turtles.<br>The Marine Park ranges in depth from less than 15 m to 800 m and provides protection for the communities and habitats of waters offshore of the Kimberley coastline. Ancient coastline and continental slope demersal fish communities are two KEFs are represented in the reserve (refer to **Section 6.4.7**) (DoEE 2018aq). |

| Marine Park | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | The Kimberley Marine Park supports or is adjacent to recreational and commercial fishing, tourism activities and areas of Native Title claims and determinations (DoEE 2018aq). |
| Mermaid Reef | 675 | The 540 km$^2$ Mermaid Reef Marine Park is a key area for over 200 species of hard corals and 12 classes of soft corals with coral formations in pristine condition. It is also an important area for sharks, marine turtles, toothed whales, dolphins, tuna and billfish. The Marine Park also has important nesting and feeding sites for migratory seabirds. Mermaid Reef Marine Park is listed on Australia's Commonwealth Heritage List due to its conservation values (DoEE 2018ah). |
| Montebello | 1,197 | The Montebello Marine Park comprises a 3,413 km$^2$ Multiple Use Zone. The area is important for foraging for migratory shorebirds, and breeding and foraging for migratory seabirds and marine turtles. It contains an important migratory pathway for humpback whales and whale sharks, and foraging areas for whale sharks. The Marine Park has a KEF; the ancient coastline at 125 m depth contour (refer to **Section 6.4.7**) (DoEE 2018ar). |
| Ningaloo | 1,181 | The Ningaloo Marine Park ranges in depth from approximately 15 to 150 m and encompasses a total area of 2,435 km$^2$. The entire Marine Park is an IUCN Category II Recreational Use Zone. The Marine Park provides foraging areas to whale sharks and marine turtles, as well as forming part of the migratory pathway for the humpback whale. This relatively shallow Marine Park provides protection for shelf and slope habitats, pinnacles and terrace seafloor features (DoEE 2018as). |
| Roebuck | 610 | The Roebuck Marine Park comprises a 304 km$^2$ Multiple Use Zone (IUCN Category VI). It includes part of the migratory pathway for humpback whales, as well as foraging areas for flatback turtles and migratory seabirds. It is adjacent to important foraging, nursing and pupping areas for freshwater, green and dwarf sawfish, and foraging and calving areas for Australian snubfin, Indo-pacific humpback and Indo-pacific bottlenose dolphins. The Marine Park provides protection for shallow shelf habitats with a depth range of 15 m to 70 m (DoEE 2018at). |
| *AMPs – NMR* | | |
| Arafura | 917 | The Arafura Marine Park is a 22,924 km$^2$ IUCN Category VI Multiple Use Zone. The Marine Park includes important resting (or internesting) areas for marine turtles, as well as important foraging habitat for breeding aggregations of the migratory roseate tern. The tributary canyons of the Arafura Depression, a unique seafloor feature, occur within this Marine Park (DoEE 2018au). |
| Arnhem | 990 | The Arnhem Marine Park ranges in depth from 5 m to 30 m. It is a 7,125 km$^2$ IUCN Category VI Special Purpose Zone. The marine park has important internesting habitat for the flatback turtle, as well as important foraging habitat for three species of tern (DoEE 2018av). |
| Joseph Bonaparte Gulf | 407 | The Joseph Bonaparte Marine Park ranges in depth from approximately 5 m to 75 m and comprises a Multiple Use Zone (IUCN Category VI) and Special Purpose Zone (IUCN Category VI) to total an area of 8,597 km$^2$. The Marine Park provides important foraging area for marine turtles and the Australian snubfin dolphin. The carbonate banks of the Joseph Bonaparte Gulf, a unique seafloor feature typified by enhanced productivity and high biodiversity, falls within this Marine Park (DoEE 2018aw). |
| Oceanic Shoals | 182 | The Oceanic Shoals Commonwealth Marine Park comprises a 71,743 km$^2$ area, with a large proportion (39,964 km$^2$) designated as Multiple Use Zone (IUCN Category VI). There are smaller areas designated for National Park Zone (Category II, 406 km$^2$), Habitat |

| Marine Park | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | Protection Zone (Category IV, 6,929 km²), and Special Purpose Zone for Trawling (Category VI, 10,461 km²). The depth ranges between approximately 5 m and 500 m. The Marine Park provides important foraging areas for loggerhead and olive ridley turtles, as well as important internesting areas for flatback and olive ridley turtles. KEFs represented in the reserve are carbonate banks, pinnacles and the shelf break and slope of the Arafura Shelf (further detail in **Section 6.4.7**) (DoEE 2018ax). |
| *WA Marine Parks* | | |
| Barrow Island Marine Park and Barrow Island Marine Management Area | > 1,263 | The Barrow Island Marine Park and Barrow Island Marine Management Area are located approximately 180 km north-east of Exmouth and encompass 42 km² and 115 km² of marine habitat respectively (DEC 2007a). The managed area is characterised by coral reefs, macroalgal and seagrass communities, subtidal soft-bottom communities, rocky shores, intertidal reef platforms and mangrove communities (DEC 2007a). These habitats in turn support nesting turtles, breeding seabird populations, humpback whales and dugongs (DEC 2007a). |
| Montebello Islands Marine Park | 1,246 | The Montebello Islands Marine Park covers approximately 583 km² and encompasses over 250 islands and islets (DBCA 2017). The habitats provided by the various reef systems, lagoons, channels and island coastline support a highly diverse array of marine flora and fauna including dugongs, cetaceans and nesting turtles (DBCA 2017). |
| Eighty Mile Beach Marine Park | 742 | The Eighty Mile Beach Marine Park covers approximately 2,000 km². Intertidal sand and mud flats within the Marine Park, support nesting flatback turtles and are recognised as a site of international importance for foraging migratory shorebirds (DPaW 2014). The Marine Park is known to have a high level of endemism and high diversity of benthic infauna (DPaW 2014). |
| Ningaloo Marine Park and Muiron Islands Marine Management Area | 1,430 | The Ningaloo Marine Park and Muiron Islands Marine Management Area encompass a 2,900 km² area within the Ningaloo Coast World Heritage Area (DBCA 2018). Both the Marine Park and Management Area include a diversity of mangrove systems, lagoons, reef, continental slope and the continental shelf habitats (DBCA 2018).<br>The Marine Park is an important feeding and breeding area for whale sharks, manta rays, marine turtles, dugongs, seabirds and cetaceans, and supports a large number of fish species. |
| Rowley Shoals Marine Park | 720 | The Rowley Shoals Marine Park (approximately 877 km²) is characterised by complex intertidal and subtidal reefs which support diverse marine fauna, including more than 233 species of coral and 688 species of fish (DEC 2007b). The reefs are thought to be a source of recruitment for invertebrates and fish on reefs further south due to conveyance by the Leeuwin Current (DEC 2007b). |
| Lalang-garram/ Horizontal Falls Marine Park and North Lalang-garram Marine Park | 330 | The Lalang-garram/Horizontal Falls and North Lalang-garram Marine Parks encompass approximately 3,530 km² and 1,100 km², respectively, and include coastal gorges, estuaries, bays, offshore islands, and a vast intertidal area (DPaW 2016a). The marine parks provide important foraging and nursery areas for dugongs, turtles, estuarine crocodile, humpback whales, dolphins, sawfish, manta rays, sea snakes and migratory seabirds and shorebirds (DPaW 2016a). The subtidal habitat also supports a diverse filter feeding community. |
| Lalang-garram/ Camden Sound Marine Park | 245 | The Lalang-garram/Camden Sound Marine Park encompasses approximately 7,050 km² of marine habitat including numerous islands and reefs (DPaW 2013). The Marine Park supports turtles, snubfin and Indo-pacific humpback dolphins, dugongs, saltwater crocodiles, and several species of sawfish (DPaW 2013). Camden Sound is also the |

| Marine Park | Approximate Distance from the Crux Platform (km) | Description |
|---|---|---|
| | | biggest calving area for humpback whales in the southern hemisphere (Jenner et al. 2001). |
| North Kimberley Marine Park | 160 | The 18,450 $km^2$ North Kimberley Marine Park features geomorphologically complex and varied seascapes and marine habitats, including bays and estuaries with mangroves, sandy beaches, coral reefs, rocky reefs, seagrass meadows and sponge gardens. There are in excess of 1,000 islands within the Marine Park which provide valuable intertidal and subtidal habitats utilised by manta rays, dugongs, dolphins, turtles, sawfish and seabirds/shorebirds (DPaW 2016b). |
| Yawuru Nagulagun/ Roebuck Bay Marine Park | 610 | The 780 $km^2$ Yawuru Nagulagun/Roebuck Bay Marine Park is recognised as being regionally, nationally and internationally significant (DPaW 2016c). Roebuck Bay in particular (a Ramsar wetland, see **Section 6.6.7**) provides habitat for internationally significant numbers of migratory birds, as well as supporting dugongs, dolphins, humpback whales and turtles (DPaW 2016c). |
| *NT Marine Parks* | | |
| Garig Gunak Barlu National Park | 814 | The marine component of the Garig Gunak Barlu National Park (previously known as the Cobourg Marine Park) encompasses the waters surrounding the Cobourg Peninsula (NT Government 2012). The National Park supports a variety of marine habitats such as rocky reefs, mangroves and mudflats, which in turn support diverse and abundant marine life, including reef and pelagic fish species, coral reefs, and seagrass. Seabirds, crocodiles, turtles and dugong are also supported by these waters (NRETAS 2011). |

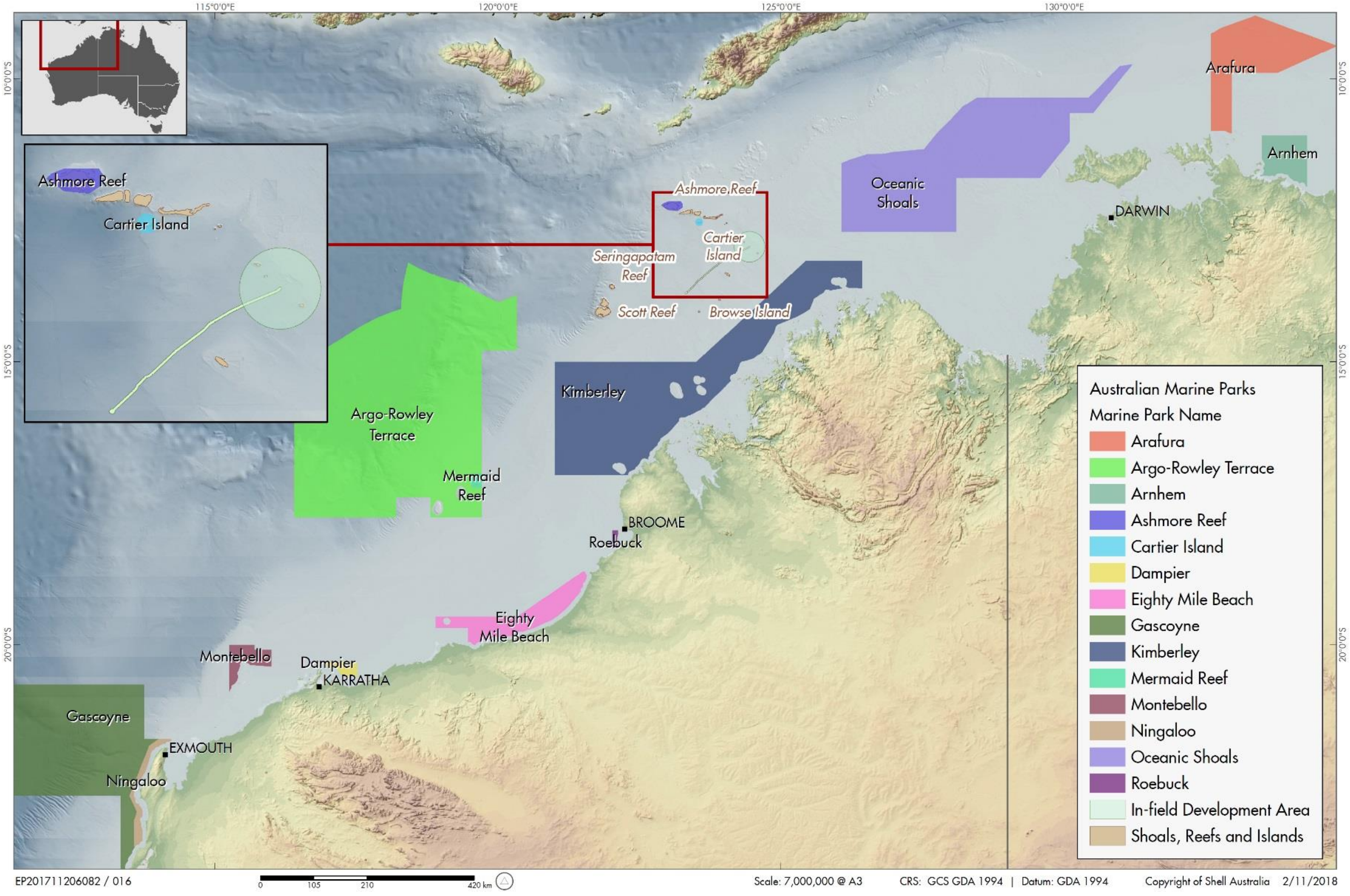



Figure 6-33: Australian Marine Parks

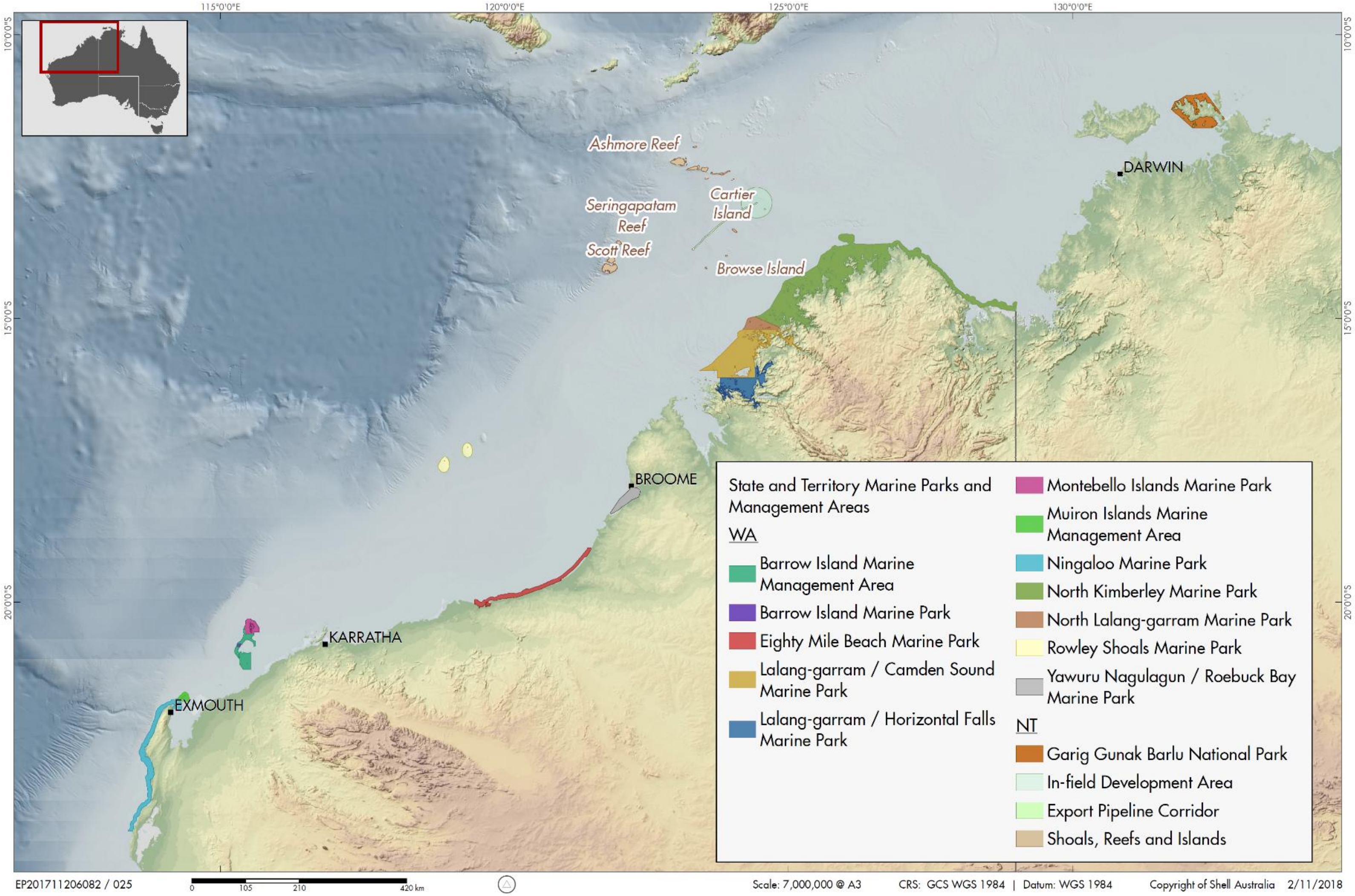



Figure 6-34: State/Territory Marine Parks/Management Areas

### 6.6.9 Commercial Fisheries

The project area overlaps with a variety of Commonwealth and WA State commercial fishing management areas, and this section identifies fisheries interests within the broader area of influence. Commercial fishing is typically concentrated mostly in coastal waters and minimum fishing effort is known to occur within the vicinity of the project area, given its remoteness offshore. This assessment will be validated through direct communication with fishers who have interests in the area (see **Section 4**).

#### 6.6.9.1 Commonwealth Fisheries

There are six Commonwealth managed commercial fisheries occurring with the area of influence (as shown in **Figure 6-35**). Of these, four fisheries management areas are indicated to overlap the project area – the North West Slope Trawl Fishery (NWSTF), Western Tuna and Billfish Fishery, Western Skipjack Fishery, and the Southern Bluefin Tuna Fishery.

A description of each of the Commonwealth managed commercial fisheries relevant to the Crux project context, with a summary of current status, is provided in **Table 6-17**.

Only one of these fisheries, the NWSTF demonstrated active fishing effort within proximity of the project area (approximately 50 km south of the export pipeline) in the 2015–16 season (Patterson et al. 2017). In addition, the Western Deepwater Trawl Fishery historically focuses fishing effort in relative proximity to the project area, however, no effort was recorded for the entire fishery during the 2015–16 season. This follows a period of reduced fishing effort over a number of years (Patterson et al. 2017).

#### 6.6.9.2 WA Managed Fisheries

There are ten WA managed commercial fisheries occurring within the area of influence (**Figure 6-36**). Of these, seven WA fisheries management areas are indicated to occur in the project area – the Northern Demersal Scalefish Fishery, Mackerel Fishery, Northern Shark Fishery, Pearl Oyster Fishery, Specimen Shell Managed Fishery, Marine Aquarium Fish Managed Fishery, and the West Coast Deep Sea Crustacean Fishery.

A description of each of the WA managed commercial fisheries relevant to the Crux project context, with a summary of current status, is provided in **Table 6-18**.

#### 6.6.9.3 NT Managed Fisheries

The project area does not directly overlap with any fisheries in NT waters. However, NT fisheries are relevant in the context of the broader area of influence and are described below for completeness.

The NT commercial fisheries occurring within the area of influence are shown in **Figure 6-37**, and further described in **Table 6-19**. These fisheries primarily operate in the NT "Top End" in nearshore island and mainland waters, including intertidal zones. Exceptions to this include the Demersal Fishery, Timor Reef Fishery, situated offshore north-west of Darwin, and the Spanish Mackerel Fishery and those fisheries targeting snapper species which are known to operate in areas further offshore.

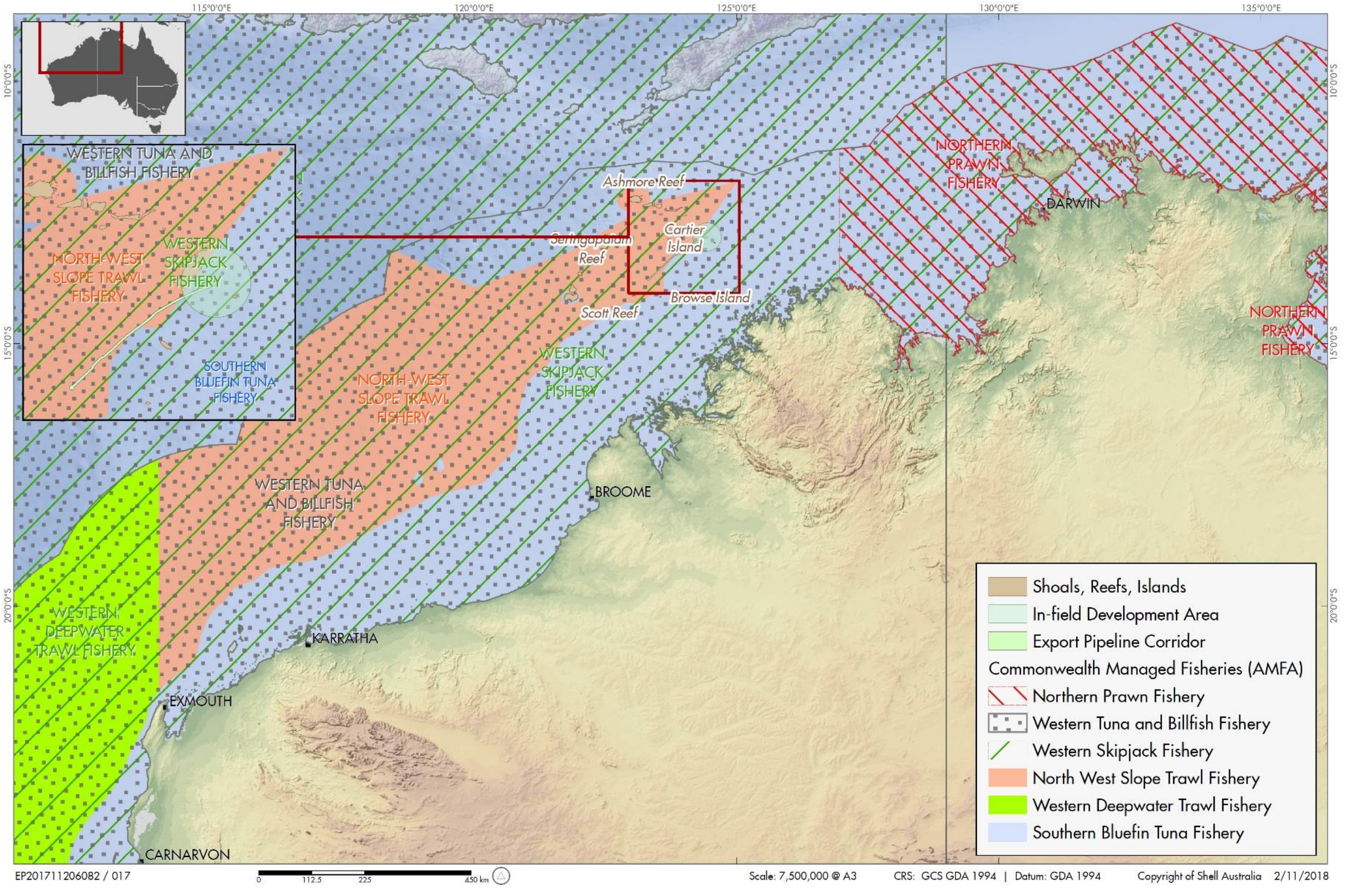



Figure 6-35: Commonwealth Managed Commercial Fisheries in the Area of Influence

Table 6-17: Commonwealth Managed Fisheries Occurring within the Area of Influence

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| North West Slope Trawl Fishery (NWSTF) | The NWSTF operates within the 200 m isobath and the AFZ, between 114 E and 125 E. The Memorandum of Understanding (MoU) box; refer to **Section 6.6.10** for detail) falls within this fishery.<br>Target species is scampi, including Australian scampi, velvet scampi and Boschma's scampi. | The NWSTF primarily uses demersal trawl methods. | Since 2008–09 the number of active fishing vessels per season has been one to two.<br>Total catch for the 2015–16 season was 54.8 tonnes from two fishing vessels, 33 tonnes of which was scampi.<br>There were five fishing permits in the 2015–16 season. |
| Western Tuna and Billfish Fishery | Fishery operates within the Australian Exclusive Economic Zone and the high seas of the Indian Ocean.<br>Key species in the fishery are swordfish, striped marlin, yellowfin tuna and bigeye tuna. | Main method is pelagic longline with some minor-line fishing. | After peaking in 2000 at 50 active vessels, fishing effort has declined and since 2005 there has been less than five vessels active each season.<br>Catch effort for the fishery was 320 tonnes in the 2016 season with 95 boat statutory fishing rights (SFRs), and three active fishing vessels.<br>Notably, whilst the fishery extends throughout the project area, fishing effort in the 2016 season did not extend north of Exmouth. Effort was concentrated off the south-west of WA and South Australia. |
| Western Skipjack Fishery | Fishery comprises the same area as the Western Tuna and Billfish Fishery.<br>Part of the Skipjack Tuna Fishery which collectively describes the Western and Eastern Skipjack Tuna Fishery. | 14 fishing permits for the 2015–16 season, no active vessels.<br>No effort since the 2008–09 fishing season, coinciding with the closure of the main cannery in Port Lincoln in 2010. | Majority of fishing effort uses purse-seine gear, small amount of pole-and-line effort. |
| Southern Bluefin Tuna Fishery | The Southern Bluefin Tuna Fishery extends throughout the AFZ.<br>There is a single spawning location for southern bluefin tuna located in the north-east Indian Ocean. Juveniles move southwards from this location along the WA coast. | 2015–16 season: 89 SFR owners; 6 active Purse-seine and 19 active long-line vessels<br>The majority of fishing effort is focused in the Great Australian Bight and waters off South Australia, targeting juveniles for transfer to aquaculture farming operations off Port Lincoln, South Australia.<br>In the 2015–16 season a total effort of 5,636 tonnes was recorded for the fishery. | The majority of catch is taken by purse-seine netting methods. Pelagic long-line (of which southern bluefin tuna is bycatch) and minor line (troll and poling) catch methods are also used. |
| Northern Prawn Fishery | The fishery extends from the NT high tide mark to the extent of the AFZ.<br>Target species include a number of tropical prawn species including white banana prawn, brown tiger | Otter trawl gear is used. | The total catch for the Northern Prawn Fishery was 5,807 tonnes in 2016, 375 tonnes of which was by-product species. Fifty-two permits were all utilised with 52 licensed vessels active in this season. |

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| | prawn, and grooved tiger prawn, which comprise 80% of catch. | | Notably, seasonal fishing effort fluctuates naturally with variability in banana prawn availability. The highest fishing effort for the Northern Prawn Fishery is concentrated within inshore coastal areas of the Gulf of Carpentaria. |
| Western Deepwater Trawl Fishery | Fishery extends seaward of approximately the 200 m depth contour<br>Target species number greater than 50, though catch is historically dominated by six commercial finfish species. In recent years, deep-water bugs (*Ibacus* spp.) have become an important target species group. | Demersal trawl fishing methods used. | There were 11 fishing permits in the 2015–16 season but no active vessels and no catch reported.<br>This follows relatively low catch levels in recent years. |

*Source: Patterson et al. 2017*

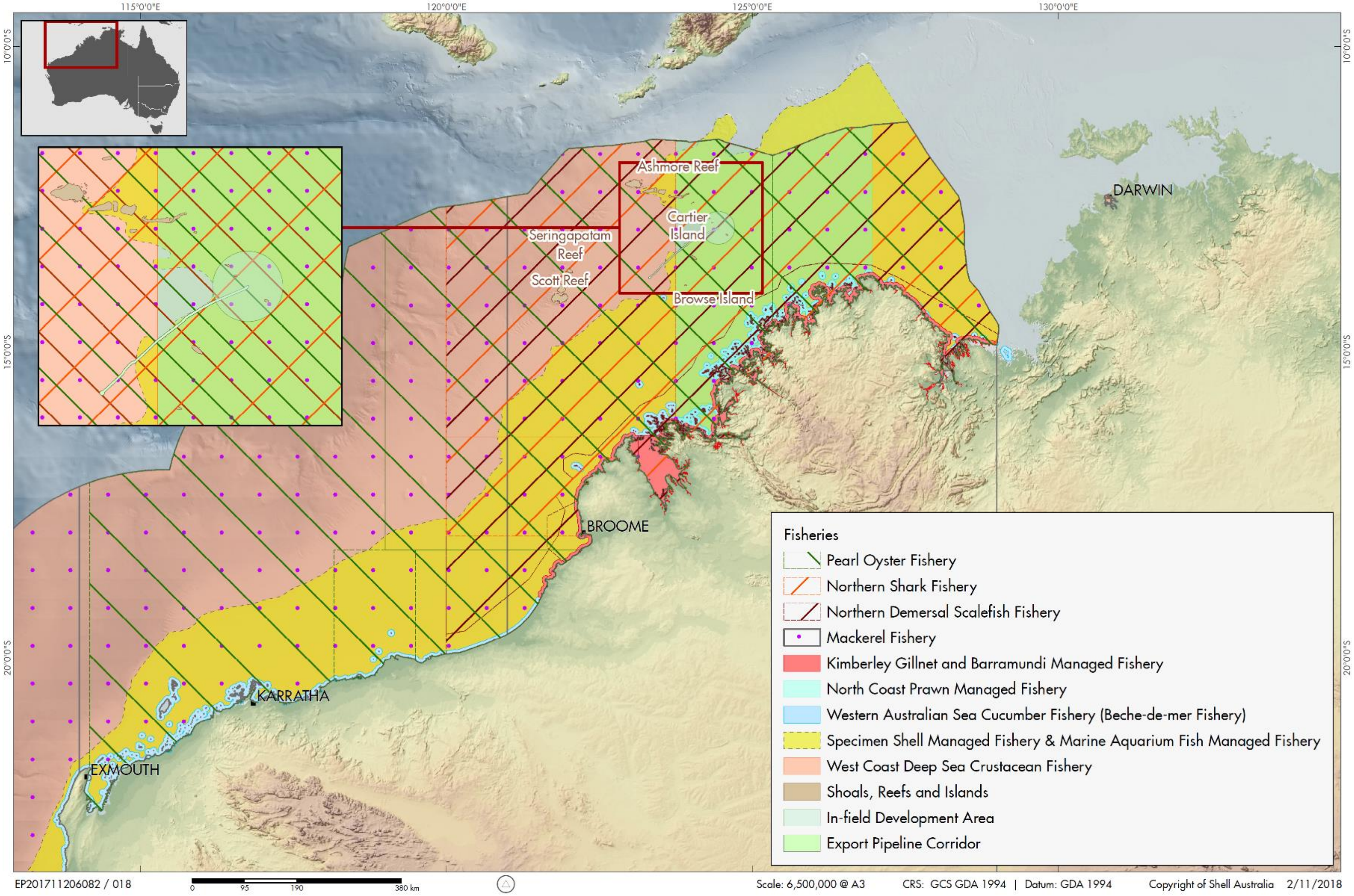



Figure 6-36: WA Managed Commercial Fisheries in the Area of Influence

Table 6-18: WA Managed Commercial Fisheries Occurring within the Area of Influence

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| Mackerel Fishery | The Mackerel Fishery extends north from the West Coast Bioregion to the NT border (DPIRD 2018a). | Dominant fishing method is trolling, also use jigging methods to catch grey mackerel in some areas (Mackie et al. 2010). | Catch effort in the 2016 season was 276 tonnes (DPIRD 2018b). The primary fishing effort is typically concentrated in the North Coast Bioregion, which encompasses the Pilbara and Kimberley coastline (DPIRD 2018a). |
| Northern Demersal Scalefish Fishery | The fishery includes all waters of the Indian Ocean and Timor Sea off the north coast of WA that are east of 120° 00.079' and north of 19°59.917'. There are some restricted areas within the fishery.<br>The fishery is divided into two fishing areas; Area 1 – inshore and Area 2 – offshore. Area 2 is further divided into Zone A, B and C (Department of Fisheries 2016). | The fishing method is restricted to either hand-line, drop-line or fish traps (Department of Fisheries 2016). | Fishing effort for the 2016 season was 1,173 tonnes (Department of Fisheries 2017). |
| Northern Shark Fishery | The Northern Shark Fishery comprises the WA North Coast Shark Fishery (Pilbara and Kimberley regions) and the Joint Authority Northern Shark Fishery (JANSF) (Eastern Kimberley) (DPIRD 2018b). | Pelagic net and longline fishery (DEH 2003). | No catch effort has been recorded since the 2008/09 season (DPIRD 2018b). |
| Pearl Oyster Fisheries | This fishery targets only the silver lipped pearl oyster (*Pinctada maxima*) and operates from Exmouth to the NT border, effort is predominately focused along the shallow coastal waters of the NWS (Fletcher et al. 2006). | This is a dive based fishery. Divers collect oysters individually as they are towed along behind the fishing vessel, using hookah or surface compressor supplied air (Fletcher et al. 2006). | Catch effort for the 2016 season was 541,260 oysters (Department of Fisheries 2017).<br>Historically as many as 16 vessels would operate each season, however, since 2009 numbers have been much lower and only 5 were active in 2013 (WAFIC 2018a). |
| North Coast Prawn Fishery | This fishery is comprised of the Onslow, Nickol Bay, Broome, and Kimberley Prawn Managed Fisheries. The fishery extends south from Cape Londonderry (and the Northern Prawn Managed Fishery boundary) to the north-eastern extent of the Exmouth Gulf Prawn Fishery (WAFIC 2018b). | Trawl fishery (WAFIC 2018b). Most of the fishing occurs at night, except for targeted fishing for banana prawns which occurs mostly during the day (DPIRD 2018c). | Catch effort from the 2016 (Department of Fisheries 2017) season was:<br>- Kimberley: 155 tonnes<br>- Nickol Bay: 17 tonnes<br>- Onslow: Negligible<br>- Broome: Negligible |
| West Coast Deep Sea Crustacean Fishery | The fishery operates off the WA coast from 34° 24' S to the NT border, from the 150 m isobath out to the Australian Exclusive Economic Zone (Department of Fisheries 2015). | Fishery uses fish traps with an average of 120 per line (Department of Fisheries 2015). | Catch effort for the 2016 season occurred primarily south of Exmouth and totalled 153.3 tonnes of crystal crab (99.6% of catch) and 30 kg of champagne crab (DPIRD 2018d). |

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| | | | |
| Specimen Shell Managed Fishery | Fishery encompasses the entire WA coastline between the high water mark and the 200 m isobath (DEH 2005b). | Dive based fishery (some new methods include controlled underwater vehicles at depths of 60 – 300 m, and baited habitat structures at depths) (DPIRD 2018d) | Primary areas of effort include Broome, Karratha, Shark Bay, metropolitan Perth, Mandurah, the Capes area and Albany. Total catch in 2016 was 8,531 shells (DPIRD 2018d). |
| Marine Aquarium Fish Managed Fishery | The fishery encompasses all WA State waters. The fishery has the capacity to target 950 marine aquarium fish species (DPIRD 2018d). | Primarily dive based using hand-held nets (DPIRD 2018d). | In recent years effort has been in waters from Esperance to Broome, with a focus around the Capes region, Perth, Geraldton, Exmouth and Dampier (DPIRD 2018b).<br>The total catch in the Marine Aquarium Fish Managed Fishery and Hermit Crab Fishery in 2016 was 128,610 fishes, 16.4 tonnes of coral, live rock and living sand, and 75 L of marine plants (DPIRD 2018d). |
| Kimberley Gillnet and Barramundi Managed Fishery | This fishery operates in nearshore and estuarine zones from the NT border to the top end of Eighty Mile Beach (DPIRD 2018d). | Gillnet fishery. | There are three principal fishing areas: Cambridge Gulf (including the Ord River), Kimberley coast (six small river systems) and King Sound (DPIRD 2018b).<br>Fishing effort for the 2016 season was 74.6 tonnes (DPIRD 2018d). |
| WA Sea Cucumber Fishery (formerly Beche-de-mer Fishery) | The fishery comprises all WA State waters (with some minor exceptions) (WAFIC 2018c). | Hand harvest (DPIRD 2018d) | There is only one active operator.<br>Catch effort for 2016 was 21 tonnes sandfish, 70 tonnes sandfish, and 2 tonnes redfish (DPIRD 2018d). |

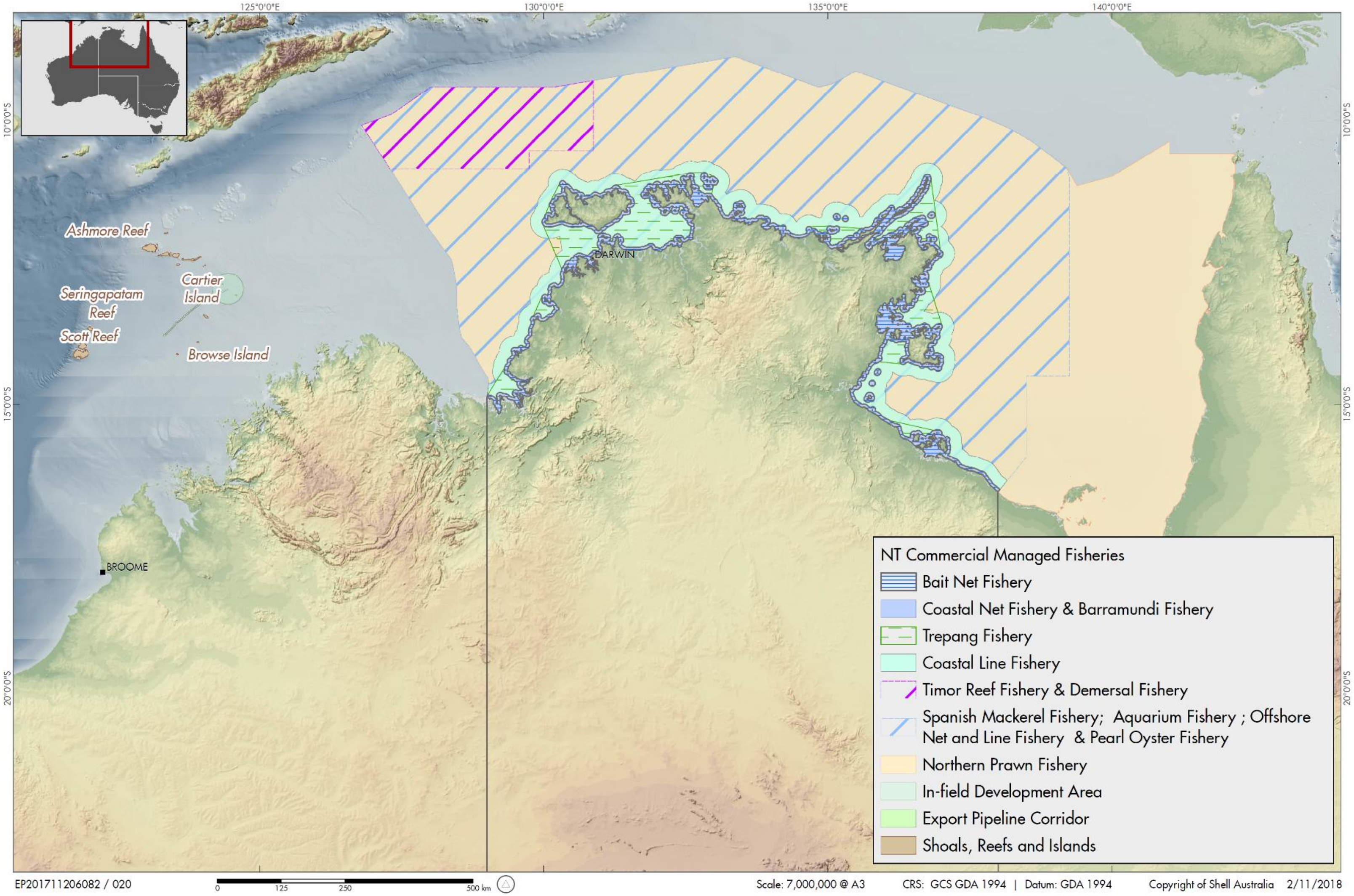



Figure 6-37: NT Managed Commercial Fisheries in the Area of Influence

Table 6-19: NT Managed Commercial Fisheries Occurring within the Area of Influence

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| Barramundi Fishery | Fishery extends from the NT coast high water mark to three nm seaward of the low water mark. Some area exclusions apply.<br>Fishing typically takes place over tidal mud flats and inside a restricted number of rivers.<br>Primary species include barramundi and king threadfin. | Use of gill nets. | Catch effort in 2015 was 661 tonnes, 58% of which was Barramundi and 38% of which was king threadfin.<br>Fishing effort is primarily focused in Anson Bay, Van Diemen Gulf, East Arnhem Land, Central Arnhem Land and Limmen Bight.<br>Fishery is restricted to 14 licences. |
| Coastal Line Fishery | Fishery extends seaward from the high water mark to 12 nm from the low water mark, within the Territory water boundaries.<br>Primary target species is Black Jewfish | Hook and line gear primarily. Also permitted to use rod and line, hand lines, cast nets (bait only), scoop nets or gaffs throughout the fishery. Restrictions apply to the use of droplines and fish traps within the fishery. | Majority of fishing effort is concentrated around rocky reeds within 150 km of Darwin.<br>2015 catch effort was 139 tonnes.<br>The fishery is limited to 52 licences. All 52 are currently allocated. |
| Coastal Net Fishery | Fishery extends seaward 3 nm from the high water mark along the NT coast.<br>Target species include mullets, blue threadfin, sharks and queenfish. | The fishery uses gill nets and cast nets which adhere to fishery specific specifications. | The fishery is limited to five licences.<br>2015 catch effort was recorded at 11.7 tonnes. |
| Spanish Mackerel Fishery | Fishery extends to the outer limit the AFZ from the high water mark, along the NT coastline.<br>Target species is Spanish Mackerel. | Trolled lines, floating hand lines or rods. | Primary fishing effort is concentrated in waters near Bathurst Island, New Year Island, the Wessel Islands and the sir Edward Pellew Group of Islands.<br>Catch effort for 2015 was 346 tonnes, 95% of which was Spanish mackerel, 5% grey mackerel.<br>The fishery is limited to 15 licences. All licences are currently allocated. |
| Demersal Fishery | Fishery extends to the outer limit of the AFZ (with exclusion of the Timor Reef Fishery area) to 15 nm from the low water mark off the NT coastline. | Demersal trawl nets are restricted to two defined zones, whereas fish traps, hand lines and droplines are permitted throughout the fishery. | Catch effort in 2015 was 3,107 tonnes, primarily comprising of rad snappers and goldband snappers.<br>There are currently 18 licences that have been issued within the fishery. Unlike other fisheries, these may not be bought or sold. |
| Offshore Net and Line Fishery | Fishery extends seaward to the outer limit of the AFZ from the high water mark of the NT coastline.<br>Target species include Australian blacktip sharks, common blacktip sharks, spottail sharks and grey mackerel. | Pelagic gillnet (primary method) and pelagic longline methods are restricted within the fishery, whereas demersal longline gear may be used throughout. | Catch effort in 2015 was 522 tonnes (78% grey mackerel).<br>The Fishery is limited to 17 licences, all of which are currently allocated. |

| Commercial Fishery | Description | Method | Number of Licences/Vessels and Effort |
|---|---|---|---|
| Mud Crab Fishery | The Mud Crab Fishery is restricted to tidal waters of the Top End. Some areas of exclusion apply including Darwin Harbour.<br>Primary target species is mud crabs, *Scylla* spp. | Baited pots, and restricted bait nets (gillnets) up to 100 m in length as crab bait within specific areas of the fishery. | There are 49 licences within this fishery and each licence holder is allowed 60 pots.<br>Catch effort is focused primarily in the Gulf of Carpentaria.<br>Catch effort in 2015 was 186 tonnes. |
| Aquarium Fish/Display Fishery | Fishery operates within tidal and non-tidal waters of the Top End out to the AFZ boundary.<br>Target species include a range of fish and invertebrates, coral rubble and live rock (substrates covered in encrusting organisms). | Various methods permitted including several types of nets, hand pumps, freshwater pots and hand-held instruments. | No record of catch effort.<br>Catch limits in place. |
| Trepang Fishery | This fishery is also known as the Sea Cucumber Fishery.<br>The Fishery extends from the high water mark of the NT coastline to 3 nm offshore.<br>Target species is sandfish and is the only species taken between 2005-15. | Hookah diving. Sea cucumbers may only be taken by hand. | Fishing effort is typically concentrated along the Arnhem land coast, from Cobourg Peninsula and Groote Eylandt.<br>There are six licences which are owned by a single entity. Each licence is restricted to four collectors. Only four of the licences were active in 2015. |
| Timor Reef Fishery | Fishery operates in an 8,400 $nm^2$ zone, known as the Timor Box, offshore north-west of Darwin bordering the NT/WA border and the AFZ.<br>Target species is tropical snapper species. | Fishing methods include baited traps, hand lines, droplines and demersal longlines.<br>Trawl gear is currently being trialled in the fishery. | Catch effort in 2015 was 806 tonnes.<br>There are currently 15 licences issued within the Fishery, licences cannot be bought or sold but new licences can be purchased. |
| Fishing Tour Operator Fishery | Typically comprised of a recreational and sport fishing client target group.<br>Target species of this fishery include sport fish, with barramundi and golden snapper forming the highest portion of catch. | Primary fishing method is hook and line. | Number of licences: Not applicable.<br>Must also hold an approved operator card as of 01/01/17.<br>Fishing effort is typically located near coastal population centres.<br>Approximately three quarters of catch is released with survivorship high for barramundi but not so for reed fish. |
| Pearl Oyster Fishery | This fishery operates from the high water mark along the NT coastline out to the AFZ. | Dive based fishery. Oysters must only be taken by hand. | There are currently five licences within this fishery.<br>Annual catch limit is 138,000 oysters for the fishery. |
| Bait Net Fishery | The fishery is limited three nm offshore of the high water mark. This excludes Darwin Harbour and Shoal Bay. | Bait net, cast net or scoop nets are permitted. | The fishery is limited to two licences which have been allocated.<br>These licences cannot be bought, leased or sold. |

*Source: NT Government 2016; NT Government 2018b*

### 6.6.10 Traditional Indigenous Fishing

In 1974, Australia recognised access rights for traditional Indonesian fishers in shared waters to the north of Australia, granting long-term fishing rights in recognition of the long history of traditional Indonesian fishing in the area (DAWR 2018). The resulting MoU between the Governments of Australia and Indonesia enables Indonesian traditional fishers to continue their customary practices. This includes the harvest of species such as trepang, trochus, clams, finfish, abalone, shark (for dried fins) and sponges in Australian waters, using traditional fishing methods only (Environment Australia 2002; DAWR 2018). This area is known as the ‘MoU Box’.

Whilst the in-field development area is located 40 km outside of the edge of the MoU Box, the export pipeline will lie within this area. Given the shallow water target species, however, traditional Indonesian fishermen are only likely to be found in deep water areas during transit to and from the reef locations; therefore, they are unlikely to be affected by project activities.

### 6.6.11 Marine Archaeology

Information on historic shipwrecks is maintained in the Australian National Shipwrecks Database (ANSD), a searchable database of Australian shipwrecks containing records provided by the Australian State and Territory Governments. A search of the ANSD did not locate any shipwrecks, aircraft wrecks or other maritime cultural heritage sites in the project area (DoEE 2018ay).

The closest shipwreck to the project is the Anne Millicent, which is approximately 108 km from the proposed Crux platform, and 78 km from the proposed export pipeline corridor at its nearest point. A number of other shipwrecks occur within the area of influence; however, these are highly unlikely to be affected given they are located on the seabed and they are distant from the project area. They include a number of unnamed Indonesian Fishing Vessels and the Sinar Bonerate in the vicinity of Ashmore Reef and Cartier Island, and the Browse Island Unident and Selina in the vicinity of Browse Island (DoEE 2018ay).

### 6.6.12 Cultural Heritage

There are no known sites of Aboriginal cultural significance within the in-field development area and there are not believed to be any along the export pipeline corridor, given that the location is more than 200 km from the mainland. Due to the distance from the mainland it is highly unlikely that the project area is used for hunting or fishing by Australian Aboriginal people. There are no islands or land within the project area and therefore there are no land based Aboriginal heritage sites. A review of the Aboriginal Heritage Inquiry System (DPLH 2018) indicates that the nearest registered sites are on the coastal islands of the Bonaparte Archipelago off the Kimberley coast, a minimum 165 km away from the proposed Crux platform.

### 6.6.13 Tourism and Recreation

Currently, there are no known recreational fishing activities in the project area as the site is too far from shore to be accessed by recreational fishermen in small boats. Even at relatively high speed (30 km/hour), it would take at least 15 hours for a recreational boat to reach the project area from the nearest port of Broome.

There are no known tourist attractions or destinations within the project area or surrounding marine waters.

Whilst charter fishing companies frequent the broader region, there are no known tourist attractions or destinations within the project area. Tourism, however, has a much larger presence along the coast from Exmouth to Darwin, largely confined to coastal waters and inshore islands, with Cape Leveque, Beagle Bay, Cockatoo Island and the Buccaneer Archipelago all being popular destinations for coastal cruises.

Fishing and diving charters operate out of Broome and Derby and the occasional charter vessel may visit Scott Reef, Ashmore Reef, Browse and Adele Island. A search of recreational fishing charters in the north-west region of WA did not reveal any recreational fishing to the marine waters representing the project area.

Birdwatching tours operate occasionally out of Broome, with annual expeditions visiting Ashmore Reef and associated offshore islands such as the Lacepede Islands, Adele Island, Browse Island, and Scott Reef.

### 6.6.14 Military/Defence

The Australian Border Force undertake civil and maritime surveillance (and enforcement) in and around the project area (Department of Home Affairs (DHA) 2018a, 2018b). The primary purpose of the activity is to monitor the passage of suspect illegal entry vessels and illegal foreign fishing activity within and beyond Australia's Exclusive Economic Zone, which extends to approximately 200 nm from the mainland (DHA 2018a).

There are no designated military/defence exercise areas in the project area and surrounds. However, regionally relevant activities include the North Australian Exercise Area (NAXA) offshore training area and the Browse Basin and Northern Carnarvon Basin offshore air-to-air weapons ranges, which are maritime military zones administered by the Department of Defence. The NAXA extends approximately 300 km north and west from just east of Darwin into the Arafura Sea and is used for offshore naval exercises and onshore weapon-firing training (Department of Defence 2015). The Browse Basin (Curtin) and Northern Carnarvon (Learmonth) situated air-to-air weapons ranges are 513 km and 1,500 km from the proposed Crux platform, respectively.

### 6.6.15 Ports and Commercial Shipping

There are no major shipping routes traversing the in-field development area or export pipeline corridor. The nearest major shipping channel is approximately 560 km to the west of the proposed Crux platform. Given the distances between the project area and shipping channels, the Crux project and related activities pose a minimal navigational risk to commercial shipping.

There may potentially be coastal ships traversing the project area supporting other petroleum activities in the vicinity, as well as the major State and Territory ports of Broome, Derby, Wyndham and Darwin. Additionally, Civil and maritime surveillance in and around the project area may occur by the Australian Border Force Maritime Border Command to monitor the passage of illegal entry vessels and illegal foreign fishing activity (DHA 2018b).

A summary of the regional shipping movements and port areas relevant to the project area is presented in **Figure 6-38**.

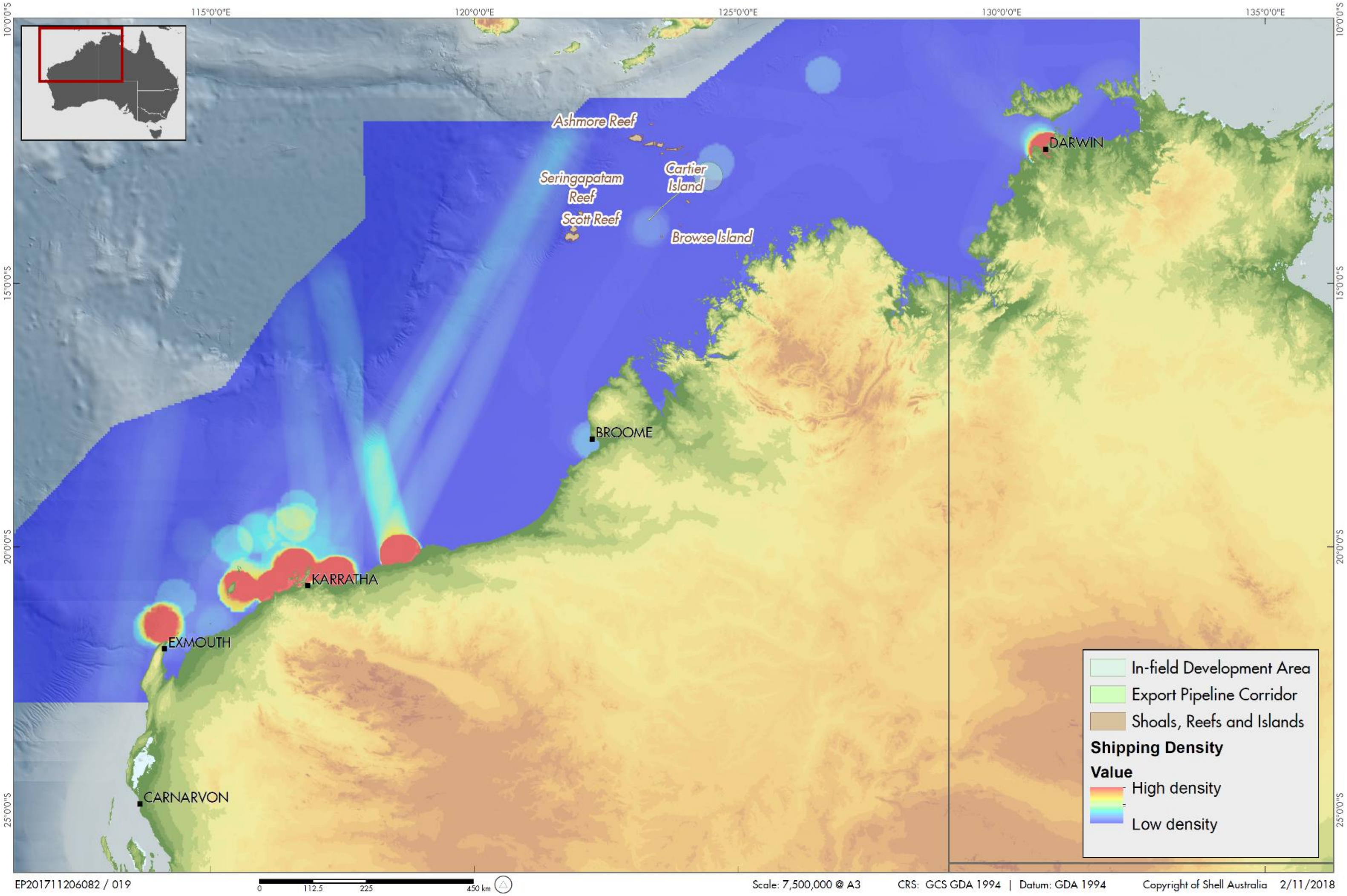



Figure 6-38: Overview of Regional Shipping Movements

### 6.6.16 Offshore Petroleum Exploration and Operations

Since the 1960s there has been significant growth in exploration, production and the oil and gas market. Energy companies have undertaken petroleum activities such as seismic and exploration in WA State and Commonwealth waters for a number of years. Specifically, petroleum exploration commenced in the Browse Basin in 1967, with several commercial discoveries since that time. The fourth well drilled in the basin, Scott Reef 1 (completed in 1971), was significant in discovering the large Torosa gas field. Since then, more than 105 wells have been drilled and there have been over 20 hydrocarbon discoveries.

The petroleum exploration and production industry is a significant user of offshore waters in northern WA, particularly within and adjacent to the Browse and Northern Bonaparte basins (DMP 2014). The closest facility to the proposed Crux platform is the Montara production FPSO facility, which is located approximately 36 km north. The Ichthys project offshore facilities are located approximately 164 km to the south-west of the proposed Crux platform, and the Prelude FLNG facility is approximately 165 km to the south-west of the Crux platform, representing the location where the export pipeline will feed into.

### 6.6.17 Indonesian and Timor-Leste Coastlines

The Indonesian and Timor-Leste Coastlines are located 280 km and 400 km north of the Crux platform and are relevant to the project in the context of the area of influence only.

Indonesia is the world’s largest archipelagic state and Indonesian waters play an important role in the global water mass transport system (ADB 2014a). Indonesia boasts some of the most biologically rich coral reefs in the world with over 590 coral species having been identified. These coastal reefs are a primary source of food and income for coastal communities, as well as forming an integral part of the countries tourism industry (ADB 2014a).

In addition to coral reefs, coastal habitats include extensive seagrass meadows, which provide habitat and foraging grounds for marine animals including dugongs and marine turtles, and mangroves, of which Indonesia has the highest plant, animal and microorganism mangrove ecosystem diversity in the world (ADB 2014a). There are also numerous cetacean species in Indonesian coastal waters.

The island of Timor is shared with Timor-Leste, which has similar coastal environmental values. Timor-Leste has a coastline of more than 700 km and a marine Exclusive Economic Zone which extends 200 nm offshore (Coral Triangle Center 2018). Notably, Timor-Leste is located in a biodiversity hotspot with a number of endemic species (Asian Development Bank (ADB) 2014b). The island has 30 declared protected areas, including Nino Konis Santana National Park which encompasses nearly 350 km$^2$ of coral reef (ADB 2014b; Coral Triangle Center 2018). The environmental values of Timor-Leste’s coastline are under pressure from illegal fishing, over-exploitation of natural resources and lack of waste management (ADB 2014b).

## 6.7 Summary of Key Values and Sensitivities of Relevance to the Project

Taking into account the existing environmental setting described in the preceding sections, the key values and sensitivities identified to be of relevance to the Crux project are summarised in **Table 6-20**.

As outlined in **Section 2.3.1**, the EPBC Act is a key piece of legislation that is applicable to the environmental management of the Crux project. MNES that may credibly interact with aspects of the Crux project include:

- World heritage properties
- National heritage places
- Wetlands of international importance
- Listed threatened species and ecological communities
- Migratory species, and
- Commonwealth marine areas.

The potential interactions are summarised in **Table 6-21**. The assessments of potential impacts and risks to MNES, including whether the impact constitutes a significant impact[1], are provided in the evaluation of environmental impacts and risks (**Section 8**).

[1] As defined by the EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DoE 2013a).

Table 6-20: Summary of Key Values and Sensitivities of Relevance to the Crux Project Context

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| *Physical Environment* | | | | | |
| Climate | Not relevant – the Crux project is not expected to influence physical climate | | | | Not applicable |
| Oceanography | Not relevant – the Crux project is not expected to influence physical oceanographic processes | | | | Not applicable |
| Bathymetry and seabed features | Y | Seabed features | Y | Seabed features | Physical environment (including seabed features, water quality, sediment quality, air quality, underwater noise) |
| Water quality | Y | Water quality | Y | Water quality | |
| Sediment quality | Y | Sediment quality | Y | Sediment quality | |
| Air quality | Y | Air quality | | Not relevant in a regional context | |
| Underwater noise | Y | Marine mammals<br>Marine reptiles<br>Sharks and rays | | Not relevant in a regional context | |
| *Ecosystems, Communities and Habitats* | | | | | |
| Marine regions and Bioregions | Not relevant - the Crux project is not expected to influence bioregional scale environment | | | | Not applicable |
| Benthic communities | Y | Benthic communities associated with predominantly silty sand or muddy sand, with some hard substrate in the shallower areas of the in-field development area. | Y | Benthic communities have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | Physical environment (seabed features) |
| Plankton | Y | Plankton present across the open ocean environment characteristic of the project area. | Y | Planktonic communities have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | Plankton |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| Shoals and banks | Y | The following shoals/banks are of relevance to the project area:<br>• Goeree Shoal – located within the in-field development area with a 1 km exclusion buffer around the shoal, 13 km north-west of the Crux platform<br>• Eugene McDermott Shoals – located within the in-field development area with a 1 km buffer, 18 km south-east of the Crux platform<br>• Vulcan Shoal – located within the in-field development area with a 1 km buffer, approximately 22 km north-west of the Crux platform | Y | The shoals/banks nearest to the project area include Goeree Shoal, Eugene McDermott Shoals, Vulcan Shoal, Barracouta Shoals, Heywood Shoals, Echuca Shoals, with other shoals and banks in the broader region.<br>These have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | Shoals and banks |
| Offshore reefs and islands | | None in the project area | Y | The offshore reefs and islands in the wider area of influence include:<br>• Ashmore Reef<br>• Cartier Island<br>• Hibernia Reef<br>• Browse Island<br>• Seringapatam Reef<br>• Scott Reef<br>• Adele Island, and<br>• other offshore reefs and islands in the broader region.<br>These have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | Offshore reefs and islands |
| WA and NT mainland coastline | | None in the project area | Y | These have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | WA and NT mainland coastline |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| Key Ecological Features | Y | Only one KEF is of relevance to the project area – the continental slope demersal fish communities KEF (intersected by the export pipeline corridor). | Y | The KEFs in the wider area of influence include:<br>• Continental slope demersal fish communities<br>• Ancient coastline at 125 m depth contour<br>• Ashmore Reef and Cartier Islands and surrounding Commonwealth waters<br>• Canyons linking the Argo Abyssal Plain with Scott Plateau<br>• Carbonate bank and terrace system of the Sahul Shelf<br>• Glomar Shoals<br>• Mermaid Reef and Commonwealth waters surrounding Rowley Shoals<br>• Pinnacles of the Bonaparte Basin<br>• Seringapatam Reef and Commonwealth waters in the Scott Reef complex<br>• Exmouth Plateau<br>• Shelf break and slope of the Arafura Shelf<br>• Carbonate bank and terrace system of the Van Diemen Rise, and<br>• Canyons Linking the Cuvier Abyssal Plain and the Cape Range Peninsula<br>• Commonwealth waters adjacent to Ningaloo Reef.<br>These have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | KEFs |
| *Threatened Species and Ecological Communities* | | | | | |
| Listed threatened and migratory species of conservation significance | Y | Potential for 20 listed threatened fauna species and 33 listed migratory species that may occur or pass through the project area. | Y | Potential for 43 listed threatened fauna species and 89 listed migratory species that may occur or pass through the area of influence. | Marine mammals<br>Marine reptiles<br>Birds |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| | | Only one BIA is of relevance to the project area – the BIA for whale shark, which represents a broad migratory corridor for this oceanic species.<br><br>The project area does not overlap any habitat critical to the survival of a species. | | The area of influence includes a number of BIAs including foraging areas for marine turtles, a migration corridor for pygmy blue whales, migration area for humpback whales, foraging areas for whale sharks, breeding/foraging/resting areas for a number of seabird and shorebird species, and a breeding, calving and foraging area for the Indo-pacific humpback dolphin.<br><br>Within the area of influence Ashmore Reef, Cartier Island and Browse Island provide critical nesting habitat for the green turtle as well as the dugong.<br><br>These have potential to be affected by the potential scenario of an unplanned (emergency) discharge. | Fish<br>Sharks and rays |
| *Socio-economic and Cultural Environment* | | | | | |
| Commonwealth Marine Area | Not relevant – there are no distinct values or sensitivities associated with this feature which are not otherwise addressed in other values and sensitivities elsewhere. | | | | Not applicable |
| Commonwealth land | - | Not relevant to the project area | Y | Ashmore Reef<br>Cartier Island (as addressed above) | AMPs |
| World Heritage Properties | - | None in the project area | Y | Kakadu National Park, which is approximately 830 km to the east of the Crux platform, is relevant only in the context of the area of influence. | World Heritage Properties |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| National Heritage Places | - | None in the project area | Y | The West Kimberley, located 169 km from the Crux platform, is a National Heritage Place relevant only in the context of the area of influence. | WA and NT Mainland Coastline |
| Commonwealth Heritage Places | - | None in the project area | Y | The following are relevant only in the context of the area of influence:<br>• Ashmore Reef National Nature Reserve<br>• Scott Reef and surrounds<br>• Mermaid Reef – Rowley Shoals<br>• North Keeling Island, and<br>• Christmas Island Natural Areas. | Other offshore reefs, islands and WA and NT mainland coastline |
| Declared Ramsar wetlands | - | None in the project area | Y | The following are relevant only in the context of the area of influence:<br>• Ashmore Reef National Nature Reserve<br>• Cobourg Peninsula<br>• “The Dales” Christmas Island<br>• Hosnies Spring Christmas Island, and<br>• Pulu Keeling National Park. | Other offshore reefs, islands and WA and NT mainland coastline |
| Australian Marine Parks | - | None in the project area | Y | The following are relevant only in the context of the area of influence:<br>• Ashmore Reef Marine Park<br>• Cartier Island Marine Park<br>• Argo-Rowley Terrace Marine Park<br>• Eighty Mile Beach Marine Park<br>• Kimberley Marine Park<br>• Dampier Marine Park<br>• Gascoyne Marine Park<br>• Mermaid Reef Marine Park<br>• Montebello Marine Park<br>• Ningaloo Marine Park<br>• Roebuck Marine Park<br>• Oceanic Shoals Marine Park<br>• Joseph Bonaparte Gulf Marine Park | Marine parks |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| | | | | • Arafura Marine Park, and<br>• Arnhem Marine Park. | |
| WA Marine Parks | - | None in the project area | Y | The following are relevant only in the context of the area of influence:<br>• Barrow Island Marine Park<br>• Barrow Island Marine Management Area<br>• Montebello Islands Marine Park<br>• Eighty Mile Beach Marine Park<br>• Ningaloo Marine Park<br>• Muiron Islands Marine Management Area<br>• Rowley Shoals Marine Park<br>• Lalang-garram/Horizontal Falls Marine Park<br>• North Lalang-garram Marine Park<br>• Lalang-garram/Camden Sound Marine Park<br>• North Kimberley Marine Park, and<br>• Yawuru Nagulagun/Roebuck Bay Marine Park. | Marine parks |
| NT Marine Parks | - | None in the project area | Y | The following is relevant only in the context of the area of influence:<br>• Garig Gunack Barlu National Park. | Marine parks |
| Commercial fisheries | Y | Commonwealth – 4 fisheries of relevance:<br>North West Slope Trawl Fishery, Western Tuna and Billfish Fishery, Western Skipjack Fishery, Southern Bluefin Tuna Fishery<br><br>WA – 7 fisheries of interest: Northern Demersal Scalefish Fishery, Mackerel Fishery, Northern Shark Fishery, Pearl Oyster Fishery, Specimen Shell Managed Fishery, Marine | Y | Commonwealth – 6 fisheries of relevance:<br>North West Slope Trawl Fishery, Western Tuna and Billfish Fishery, Western Skipjack Fishery, Southern Bluefin Tuna Fishery, Northern Prawn Fishery, Western Deepwater Trawl Fishery.<br><br>WA – 10 fisheries of interest: Northern Demersal Scalefish Fishery, Mackerel | Commercial fisheries |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| | | Aquarium Fish Managed Fishery, West Coast Deep Sea Crustacean Fishery | | Fishery, Northern Shark Fishery, Pearl Oyster Fishery, Specimen Shell Managed Fishery, Marine Aquarium Fish Managed Fishery, West Coast Deep Sea Crustacean Fishery, Kimberley Gillnet and Barramundi Managed Fishery, North Coast Prawn Managed Fishery, Western Australian Sea Cucumber Fishery (Beche-de-mer Fishery).<br><br>Up to 13 NT managed commercial fisheries overlap the area of influence. | |
| Traditional Indigenous fishing | Y | MoU Box – while 70 km away from the Crux platform location, the export pipeline will transect this area.<br>Potential for low level traditional Indonesian fishing activity in the area. | Y | MoU Box, traditional/customary fishing by Indonesian fishermen and Indigenous fishing around the WA and NT coastline and surrounding nearshore islands in the area of influence. | Indigenous fishing |
| Marine archaeology | - | None in the project area | Y | The nearest shipwreck to the project area is the Ann Millicent (approx. 108 km NW of the Crux platform, near Cartier Island). Additionally, there are five unnamed wrecked Indonesian fishing vessels and the Sinar Bonerate shipwreck in the vicinity of Ashmore Reef and Cartier Island. These shipwrecks are Federally protected.<br><br>There are a number of additional shipwrecks within the area of influence (including at Browse Island). | Marine archaeology |
| Cultural heritage | - | Not relevant to the project area | Y | The northern Kimberley coastline, and surrounding offshore islands, is of high intrinsic indigenous heritage value. Similarly, the NT coastline and offshore islands (e.g. Tiwi Islands) is of high indigenous heritage value. | Other offshore reefs, islands and WA and NT mainland coastline |

| Value/Sensitivity | Present in the Crux Project Area | Particular Values/Sensitivities of Relevance | Present in the Area of Influence | Particular Values/Sensitivities of Relevance | Factor Category in the Evaluation of Environmental Impacts and Risks (Section 8) |
|---|---|---|---|---|---|
| | | | | These are relevant only in the context of the area of influence. | |
| Tourism and recreation | | Not relevant to the project area | Y | There is potential for low intensity tourism and recreational marine users in the offshore marine environment, including around the offshore islands and reefs in the region. | Tourism and recreation |
| Military/defence | | Not relevant to the project area | Y | Defence activities are expected to occur in the offshore marine environment in the region. | Defence activities |
| Ports and commercial chipping | | Not relevant to the project area | Y | While no major shipping routes traverse the project area, commercial shipping transits through the offshore marine environment in the region. | Ports and commercial shipping |
| Offshore petroleum exploration and operations | | Not relevant to the project area | Y | The closest facility to the proposed Crux platform is the Montara production FPSO facility, which is located approximately 36 km north. | Offshore petroleum exploration and operations |
| Indonesian and Timor-Leste coastlines | | Not relevant to the project area | Y | The Indonesian and Timor-Leste Coastlines are relevant only in the context of the area of influence. | Indonesian and Timor-Leste coastlines |

Table 6-21: Potential Interactions between MNES and Aspects of the Crux Project

| MNES Category | MNES Sub-category | Aspects | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Physical Presence and Vessel Movements (Sections 5.7.1 and 5.7.2) | Light Emissions (Section 5.7.3) | Underwater Noise (Section 5.7.4) | Atmospheric Emissions (Section 5.7.5) | Invasive Marine Species (Section 5.7.6) | Waste Management (Section 5.7.8) | Liquid Discharges (Section 5.7.7) | Unplanned Spills (Section 5.7.9) |
| **World Heritage Properties (Section 6.6.4)** | **N/A** | No | No | No | No | No | No | No | Yes (Section 8.4.9) |
| **National Heritage Places (Section 6.6.5)** | **N/A** | No | No | No | No | No | No | No | Yes (Section 8.4.9) |
| **Wetlands of International Importance (Section 6.6.7)** | **N/A** | No | No | No | No | No | No | No | Yes (Section 8.4.9) |
| **Listed Threatened Species and Ecological Communities**<br><br>**Listed Migratory Species (Section 6.5.1)** | **Marine mammals** | Yes (Section 8.4.1) | Yes (Section 8.4.2) | Yes (Section 8.4.3) | No | No | Yes (Section 8.4.7) | Yes (Section 8.4.8) | Yes (Section 8.4.9) |
| | **Marine reptiles** | Yes (Section 8.4.1) | Yes (Section 8.4.2) | Yes (Section 8.4.3) | No | No | Yes (Section 8.4.7) | Yes (Section 8.4.8) | Yes (Section 8.4.9) |
| | **Birds** | No | Yes (Section 8.4.2) | No | No | No | Yes (Section 8.4.7) | No | Yes (Section 8.4.9) |
| | **Sharks and rays** | Yes (Section 8.4.1) | Yes (Section 8.4.2) | Yes (Section 8.4.3) | No | No | Yes (Section 8.4.7) | Yes (Section 8.4.8) | Yes (Section 8.4.9) |
| **Commonwealth Marine Area (Section 6.6.3)** | **N/A** | Yes (Section 8.4.1) | Yes (Section 8.4.2) | Yes (Section 8.4.3) | Yes (Section 8.4.4) | Yes (Section 8.4.5) | Yes (Section 8.4.7) | Yes (Section 8.4.8) | Yes (Section 8.4.9) |

# 7 Acceptable Levels of Impact and Risk for the Crux Project

The OPGGS (E) Regulations require the proponent include an evaluation of all the impacts and risks that reaches a conclusion on whether the impacts and risks will be of an 'acceptable' or 'unacceptable' level. To this end, Shell has determined acceptable levels of impact to the environmental receptors that may credibly be impacted by the Crux project. The process by which Shell has determined the acceptability of risks and impacts is detailed below.

## 7.1 Considerations in Developing Defined Acceptable Levels of Impact and Risk

Shell has established defined acceptable levels of impacts and risks for the Crux project relating to all the environmental receptors that were identified as being credibly impacted by, or at risk of impacts from aspects. The outcomes of the evaluation of environmental impacts and risks were assessed against these defined acceptable levels to demonstrate if the impacts or risks meet the acceptable levels of impact or not.

The following were considered when establishing the acceptable levels of impacts and risks outlined in **Section 8**:

- The principles of ecologically sustainable development (ESD)
- Other requirements applicable to the Crux project (e.g. laws, policies, standards, conventions etc.), including significant impacts[2] to MNES
- Internal context, and
- External context.

Each of these considerations are elaborated on below.

### 7.1.1 Principles of ESD

Shell has considered the principles of ESD in defining acceptable levels of impacts and risks, as defined in Section 3A of the EPBC Act. The principles of ESD are summarised as:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- The principles 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 conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.
- Improved valuation, pricing and incentive mechanisms should be promoted.

[2] Significant impacts refer specifically to the levels of impacts defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoE 2013a). Any subsequent reference in this OPP to significant impacts refers to these levels unless stated otherwise.

### 7.1.2 Other Requirements

Shell considered other requirements that apply to the environmental management of the Crux project, including legislation, policies, standards and guidelines in establishing acceptable levels of impacts and risks (refer to **Section 2.3**). Given the Crux OPP forms the basis for NOPSEMA's assessment of matters protected under Part 3 of the EPBC Act in Commonwealth waters, Shell has given attention to the acceptability of impacts and risks to MNES. The potential interactions between MNES and aspects of the Crux project are provided in **Table 6-21**.

Where a potential interaction between MNES and an aspect of the Crux project was identified, the criteria provided in **Table 7-1** were considered. Potential impacts and risks to MNES from aspects of the Crux project were inherently acceptable if:

- The significant impact criteria in relation to the MNES were not exceeded, and
- The management of the aspect is aligned with published guidance material from the DoEE, including threat abatement plans, recovery plans and conservation advice.

Table 7-1: MNES Significant Impact Criteria of Relevance to the Crux Project

| Category | Significant Impact Criteria |
|---|---|
| **Critically Endangered and Endangered species** | An action is likely to have a significant impact on critically endangered or endangered species if there is a real chance or possibility that it will:<br>• Lead to a long-term decrease in the size of a population,<br>• Reduce the area of occupancy of the species,<br>• Fragment an existing population,<br>• Adversely affect habitat critical to the survival of a species,<br>• Disrupt the breeding cycle of a population,<br>• Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,<br>• Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat,<br>• Introduce disease that may cause the species to decline, or<br>• Interfere with the recovery of the species. |
| **Vulnerable species** | An action is likely to have a significant impact on vulnerable species if there is a real chance or possibility that it will:<br>• Lead to a long-term decrease in the size of an important population,<br>• Reduce the area of occupancy of and important population,<br>• Fragment an existing important population into two or more populations,<br>• Adversely affect habitat critical to the survival of a species,<br>• Disrupt the breeding cycle of a population,<br>• Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,<br>• Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat,<br>• Introduce disease that may cause the species to decline, or<br>• Interfere substantially with the recovery of the species. |
| **Migratory Species** | An action is likely to have a significant impact on migratory species if there is a real chance or possibility that it will:<br>• Substantially modify, destroy or isolate an area of important habitat for a migratory species,<br>• Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or<br>• Seriously disrupt the lifecycle of an ecologically significant proportion of the population of a migratory species. |

| Category | Significant Impact Criteria |
|---|---|
| **Wetlands of International Importance** | An action is likely to have a significant impact on a wetland of international importance if there is a real chance or possibility that it will result in:<br>• Areas of wetland being destroyed or substantially modified,<br>• A substantial and measurable change in the hydrological regime of the wetland,<br>• The habitat or lifecycle of native species dependent upon the wetland being seriously affected,<br>• A substantial and measurable change in the water quality of the wetland which may adversely impact on the biodiversity, ecological integrity, social amenity or human health, or<br>• An invasive species that is harmful to the ecological character of the wetland being established in the wetland. |
| **Commonwealth Marine Environment** | An action is likely to have a significant impact on the environment in a Commonwealth marine area if there is a real chance or possibility that it will:<br>• Result in a known or potential pest species becoming established in the Commonwealth marine area,<br>• Modify, destroy, remove, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity on a Commonwealth marine area results,<br>• Have a substantial adverse effect on a population of a marine species or cetacean including its life cycle and spatial distribution,<br>• Result in a substantial change in air quality or water quality which may adversely impact on biodiversity, ecological integrity[3], social amenity or human health,<br>• Result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected, or<br>• Have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck. |

[3] In the context of the Crux project, a change to ecological integrity is considered to take into account broadscale, long term impacts to the ecosystem. With regards to the Commonwealth marine environment, the Crux project area is located in open offshore waters and the seabed is generally characterised by smooth predominantly sandy sediments and is bare of hard substrates. These characteristics are typical of the offshore Browse Basin.

**Significant Impacts and Impacts – What's the difference?**
When determining the acceptability of an environmental impact, Shell references significant impacts and impacts. These are two related, but distinct, concepts used when determining if an impact or risk is acceptable.

Significant impacts refer to the Matters of National Environmental Significance - Significant impact guidelines 1.1 published by the DoEE (DoE 2013a). These guidelines assist proponents and regulators in determining if an activity has the potential to significantly impact upon MNES, which are protected under Part 3 of the EPBC Act. There are several potential interactions between aspects of the Crux project and MNES. Shell has used the significant impact criteria defined in the MNES - Significant impact guidelines 1.1 to assist in determining the acceptable levels of impact, along with other material published by the DoEE.

Significant impacts can also include indirect, or offsite, impacts. These include:

- 'downstream impacts', such as a reduction in water quality from the discharge of drill cuttings and fluids down current from a MODU,
- 'upstream impacts', such as the extraction of materials and energy used to undertake an activity, and
- 'facilitated impacts', which result from future actions that are enabled as a result of the Crux project.

In comparison, Shell considers an impact to be any effect on an environmental receptor. This includes any changes to the environmental receptors that may be considered harmful, or even beneficial (e.g. an increase in the diversity of benthic communities from the creation of artificial reefs by subsea infrastructure).

Based on these definitions, all significant impacts are impacts, but not all impacts are necessarily significant impacts. A significant impact will generally have greater potential for environmental harm than an impact that is not significant.

**Additional Considerations for Significant Impacts to MNES**
Where an impact or risk was evaluated as having the potential to exceed any significant impact criteria, additional consideration was given to the establishment of acceptability of the impact or risk. This additional consideration is reflected in the EPOs for aspects that may exceed the significant impact criteria.

A conceptual diagram showing the relationship between the significant impact criteria, aspects and potential for impacts and risks is provided in Figure 7-1. In this diagram, aspects 1, 2 and 4 do not exceed the significant impact criteria and hence are acceptable in relation to MNES (assuming the aspect is aligned to the requirements of MNES-specific advice published by the DoEE). Aspects 3 and 5 exceed the significant impact criteria for MNES. These aspects pose a greater risk to MNES and require additional consideration of acceptable levels of impacts and risks beyond the significant impact criteria.

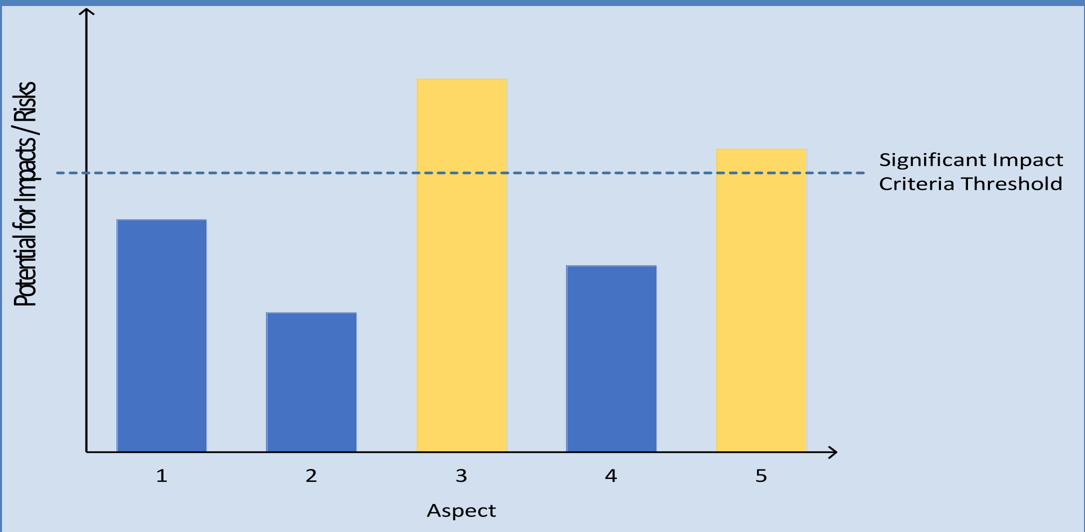



Figure 7-1: Conceptual Diagram Showing the Relationship between the MNES Significant Impact Criteria Threshold, Aspects and Potential for Impacts or Risks

### 7.1.3 Internal Context

Shell considered its internal context when establishing acceptable levels of impacts and risks. This context included Shells environment policy, environmental risk management framework, technical guidance material and opinions of internal stakeholders.

Details of Shell's impact assessment methodology referred to below can be found within Section 8.3. The following outlines Shell's internal impact and risk assessment defined acceptable levels:

- residual planned impacts that are ranked as minor or less (i.e. minor, slight, no effect or positive effect) and residual risks for unplanned events ranked negligible and minor, are inherently 'acceptable', if they meet legislative and Shell requirements and the established acceptable levels of impacts and risks.
- moderate residual impacts, and moderate and major residual risks, are 'acceptable' if good industry practice can be demonstrated. In this acceptability evaluation, in addition to the considerations above, the following points are also considered:
  - internal context – the proposed controls are consistent with Shell policies, procedures and standards
  - external context – consideration of stakeholder expectations, objections and claims, and
  - other requirements – the proposed controls are consistent with national and international standards, laws and policies.
- major and massive magnitude effects from planned impact, and massive residual risks from unplanned risks, are 'unacceptable'. The activity (or element of) should not be undertaken as the impact or risk is serious and does not meet the principles of ESD, legal requirements, Shell requirements or regulator and stakeholder expectations. The activity requires further assessment to reduce the risk to an acceptable level.

**Table 7-2** provides a summary of the acceptability statements, as correlated to the risk rankings presented in **Table 8-4** (for planned impacts/risks) and **Table 8-6** (for unplanned impacts/risks).

Table 7-2: Acceptability Categories

| Acceptability Statement | Residual Impact (Planned) | Residual Risk (Unplanned) |
|---|---|---|
| Inherently acceptable | • Positive effect<br>• No effect<br>• Slight<br>• Minor | • No effect<br>• Negligible<br>• Minor |
| Acceptable with controls | • Moderate | • Moderate<br>• Major |
| Unacceptable | • Major<br>• Massive | • Massive |

### 7.1.4 External Context

Shell also considered the external context when establishing acceptable levels of impacts and risks. This includes any available information provided by stakeholders during the preparation of the Crux OPP. Shell acknowledges the public comment period on the Crux OPP will provide additional external context and will consider the views of stakeholders providing comment on the Crux OPP. This will be incorporated into the revision of the Crux OPP submitted to NOPSEMA for assessment following the public comment period.

## 7.2 Defined Acceptable Levels of Impact and Risk for the Crux Project

The acceptable levels of impacts and risks to environmental receptors from the Crux project are summarised in **Table 7-3**.

Table 7-3: Summary of Acceptable Levels of Impact for Environmental Receptors that may be Impacted by Aspects of the Crux Project

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Justification |
|---|---|---|---|
| **Physical Environment** | **Water quality** | No significant impacts to water quality during the Crux project. | The routine discharge of PFW at the Crux platform may result in impacts in the immediate area of the Crux platform. Modelling studies indicate the impacts will be localised around the Crux platform (characterised as open offshore waters, typical of the offshore Browse Basin) and will persist during the operational phase of the Crux project. Liquid discharges from the Crux project cannot be avoided. However, the area influenced from routine operational discharges is expected to be limited to within 1 km of the liquid discharge locations. The potential magnitude of impacts to marine ecosystems is very low. Given the offshore location and absence of particularly sensitive marine ecosystems at the Crux platform location and immediate surrounds, potential impacts within 1 km of the Crux platform are considered acceptable.<br>Bakke et al. (2013) states that typically no impacts are detected beyond 2 km from offshore facilities around the world. The nearest sensitive habitat to the Crux platform is Goeree Shoal, approximately 13 km away.<br>Other discharges, such as hydrotest water and utility discharges from vessels, are of typically short duration and will not have the potential for significant impacts over an extended period. |
| | **Sediment quality** | No significant impacts to sediment quality during the Crux project. | The discharge of drill cuttings and fluids may result in elevated levels of potential contaminants near wells, such as the foundation wells at the Crux platform, or the Crux platform foundations. Additionally, the discharges from the Crux platform (e.g. drainage water) may also increase the concentration of potential contaminants around the Crux platform. Sediment quality in the vicinity of the Crux in-field development area is characteristic of the sediment quality conditions of the offshore region.<br>Bakke et al. (2013) states that typically no impacts are detected beyond 2 km from offshore facilities around the world.<br>Impacts to sediment quality from the Crux project cannot be avoided. However, the area influenced is expected to be limited to within 1 km of sources of potential sediment contamination (e.g. drilling locations and the Crux platform). The potential magnitude of impacts to marine ecosystems is very low and localised. These impacts are considered to be acceptable when considering the seabed is smooth and bare of hard substrates, with predominantly sandy sediments observed. |
| | **Air quality** | No significant impacts to air quality during the Crux project. | Planned atmospheric emissions from the Crux project consist primarily of combustion engine exhaust emissions (e.g. gas turbine generators on the Crux platform, vessel engines etc.). Small quantities of fugitive emission from hydrocarbon processing infrastructure will also |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Justification |
|---|---|---|---|
| | | | occur. These emissions will be in accordance with relevant requirements, such as Australian GHG reporting and MARPOL air pollution requirements.<br>The Crux project is located in the open ocean, and is well-removed from nearest residential or sensitive populations of the WA coast, with limited interaction with regional airsheds. |
| **Ecosystems, Communities and Habitats** | **Benthic communities** | No significant impacts to benthic habitats and communities.<br>No direct loss of coral communities on the outcropping reef as a result of future tie-backs to the Crux platform. Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | With the exception of banks and shoals, the benthic habitats and communities within the Crux project area are widely represented in the Timor Sea, with millions of hectares of broad soft benthic habitats occurring in the region and they are not of high environmental value. The outcropping reef feature, identified within the Crux in-field development area, forms part of an extensive seabed ridge and surveys indicate this feature does not support highly diverse benthic communities, such as those characteristic of shoals and banks within the region. With the exception of banks and shoals, impacts to benthic habitats within the Crux project area are acceptable if the area impacted is < 5% of the total project area. |
| | **Shoals and banks** | No direct impacts to named banks and shoals.<br>No loss of coral communities at named banks or shoals as a result of indirect/offsite[4] impacts associated with the Crux project. | The shoals and banks of the Timor Sea, including the three shoals within the boundary of the Crux in-field development area, are of high environmental value. Shell considers direct impacts to these features unacceptable. Indirect impacts are considered acceptable (e.g. minor pulsed turbidity events) if they do not result in any loss of coral communities, i.e. the loss of a coral colony that occurs on the shoal (noting, there is both temporal and spatial variability of corals as a result of natural environment influences, such as storms/cyclones and coral bleaching). The representativeness of coral communities is considered an indicator contributing to high biological diversity and ecological value (refer to **Section 6.4.4.1** for further discussion). In the context of this assessment, a coral colony is considered integral to maintaining the ecological function and integrity of a coral community in a spatial and temporal context. |
| | **Offshore reefs and islands** | No impacts to offshore reefs and islands. | Offshore reefs and islands would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **WA and NT mainland coastline** | No impacts to WA and NT mainland coastline. | The WA and NT mainland coastline would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **Key Ecological Features** | No significant impacts to environmental values of KEFs. | KEFs in the Timor Sea are largely geomorphic features that provide important ecosystem services primarily as a result of their unique physical features (e.g. provision of hard substrates, facilitation of upwelling etc.). These are geographically diverse features that cover |

[4] As defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoE 2013a).

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Justification |
|---|---|---|---|
| | | | a large extent. Only one KEF is intersected by the Crux project, with the export pipeline intersecting a small portion of the continental slope demersal fish communities (0.04%).<br>Given the nature and scale of the planned impacts to KEFs from the Crux development, impacts to KEFs will be below the significant impact threshold. Shell considers impacts to KEFs below this threshold to be acceptable. |
| **Threatened Species and Ecological Communities** | **Marine mammals**<br>**Marine reptiles**<br>**Birds**<br>**Fish**<br>**Sharks and rays** | No mortality or injury of threatened or migratory MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory MNES fauna. | Shell considers any mortality or injury of threatened species that are MNES to be unacceptable for the Crux project.<br>Impacts that are below the significant impact threshold are acceptable. |
| **Socio-economic and Cultural Environment** | **Commonwealth Marine Area** | No significant impacts to the Commonwealth marine area beyond 1 km from the Crux platform or drilling locations. | Discharges at the Crux platform may result in impacts to water and sediment quality, both of which are components of the Commonwealth marine environment, within 1 km of the Crux platform or drilling locations. As outlined above in the Water Quality and Sediment Quality sub-categories, routine impacts to water and sediment quality are expected to be limited to within 1 km and are considered acceptable as the potential impacts to the marine ecosystem (functioning and integrity) is very low when considering the discharge location and the nature of the receiving environment (open offshore waters, and with seabed characterised to be smooth and bare of hard substrates, with predominantly sandy sediments observed). Impacts beyond this range are unacceptable. |
| | **World Heritage Properties** | No impacts to world heritage values. | World heritage values would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional environmental context, the nearest world heritage property is 800 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **National Heritage Places** | No impacts to national heritage values. | National heritage values would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional environmental context, the nearest national heritage place is 170 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **Commonwealth Heritage Places** | No impacts to Commonwealth heritage values | Commonwealth heritage values would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional environmental context, the nearest Commonwealth heritage place is 149 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Justification |
|---|---|---|---|
| | **Declared Ramsar Wetlands** | No impacts to ecological values of Ramsar wetlands | Ramsar wetlands would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional environmental context, the nearest Ramsar wetland is 149 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **Marine Parks** | No impacts to the values of marine parks | The environmental values within Australian marine parks would only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional environmental context, the nearest Marine Park is 95 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |
| | **Commercial fisheries** | No negative impacts to exploited fisheries resource stocks which result in a demonstrated direct loss of income.<br>Temporary displacement of commercial fishing activities within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of commercial fishing activities from gazetted petroleum exclusion zones is acceptable. | Impacts to commercially exploited fish stocks may measurably reduce the potential revenue for commercial fishers. Shell considers this to be unacceptable.<br>In a regional context, commercial fishing is typically concentrated mostly in coastal waters and minimum fishing effort is known to occur within the vicinity of the project area, given its remoteness offshore.<br>Shell considers the displacement of other users (e.g. commercial fishers) from relatively small areas of the open ocean environment in the Crux project area to be acceptable. |
| | **Traditional Indigenous fishing** | No negative impacts to exploited fisheries resource stocks.<br>Temporary displacement of traditional fishing activities within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of traditional fishing activities from gazetted petroleum exclusion zones is acceptable. | Impacts to traditionally exploited fish stocks may deprive traditional fishers of the benefits provided by the environment. Shell considers this to be unacceptable.<br>In a regional context, the in-field development area is located 40 km outside of the edge of the MoU Box for traditional indigenous fishing, while the export pipeline will lie within this area.<br>Shell considers the displacement of other users (e.g. traditional indigenous fishers) from relatively small areas of the open ocean environment in the Crux project area to be acceptable. |
| | **Marine archaeology** | No disturbance to historical shipwrecks is acceptable. | Shell considers any disturbance of historical shipwrecks to be unacceptable.<br>In a regional context, the nearest known historical shipwreck is 108 km away from the Crux platform, and 78 km from the export pipeline corridor at its nearest point. |
| | **Tourism and recreation** | No negative impacts to nature-based tourism resources resulting in demonstrated loss of income. | Impacts to nature-based tourism resources may deprive the tourism industry of revenue. Shell considers this to be unacceptable. |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Justification |
|---|---|---|---|
| | | Temporary displacement of tourism activities within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of tourism activities from gazetted petroleum exclusion zones is acceptable. | In a regional context, there are no known tourist attractions or destinations within the project area or surrounding marine waters, however charter vessels may transit the broader regional waters.<br>Shell considers the displacement of other users (e.g. tourism operators) from the Crux project area, which is a relatively small area of the open ocean environment where existing tourism and recreation use is very low, to be acceptable. |
| | **Military/defence** | Temporary displacement of defence activities within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of defence activities from gazetted petroleum exclusion zones is acceptable. | Shell considers the displacement of other users (e.g. defence vessels and aircraft) from relatively small areas of the open ocean environment in the Crux project area to be acceptable.<br>In a regional context, there are no designated military/defence exercise areas in the Crux project area and surrounds, however there are regional defence exercise areas with large geographic extents. |
| | **Ports and commercial shipping** | Temporary displacement of commercial shipping within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of commercial shipping from gazetted petroleum exclusion zones is acceptable. | Shell considers the displacement of other users (e.g. commercial shipping) from relatively small areas of the open ocean environment in the Crux project area to be acceptable.<br>In a regional context, there are no major shipping routes traversing the in-field development area or export pipeline corridor. The nearest major shipping channel is approximately 560 km to the west of the proposed Crux platform. |
| | **Offshore petroleum exploration and operations** | Temporary displacement of petroleum exploration activities and operations within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of petroleum exploration activities and operations from gazetted petroleum exclusion zones is acceptable. | Shell considers the displacement of other users (e.g. petroleum exploration and operations) from relatively small areas of the open ocean environment in the Crux project area to be acceptable.<br>In a regional context, the nearest operational facility to the Crux platform is the Montara production FPSO facility, approximately 36 km away. |
| | **Indonesian and Timor-Leste coastlines** | No impacts to Indonesian or Timor-Leste coastlines are acceptable. | The Indonesian and Timor-Leste coastlines could only be impacted by a large-scale hydrocarbon spill, such as a well blowout. In a regional context, these coastlines are located a minimum 280 km away. Shell considers any large-scale hydrocarbon spill to be unacceptable. |

# 8 Evaluation of Environmental Impacts and Risks

## 8.1 Introduction

This section documents the process that identifies and evaluates potential environmental impacts and risks and develops means of mitigating the impacts of the proposed Crux project on the environment, including socio-economic, cultural and human-health impacts.

It describes the approach undertaken to evaluate the magnitude of impact to environmental and social receptors from activities associated with the Crux project. This description includes the identification of potential impacts and benefits, and the evaluation of their significance.

The proposed management controls form the basis of the Environmental Performance Framework (refer **Section 9**) which will be implemented during the Crux project.

## 8.2 Shell Company Approach to Risk Management

At a corporate level, Shell has a standardised Hazards and Effects Management Process (HEMP), as the process by which Shell identifies and assesses hazards, implements measures to manage them. This process is consistent with the principles outlined in the Australian Standard AS/NZS ISO 31000:2009 Risk Management and Handbook 203:2006 Environmental Risk Management (**Figure 8-1**). HEMP is a fundamental element of the Shell Group HSSE and SP Control Framework and is a process that is applied at every phase of projects and operations.

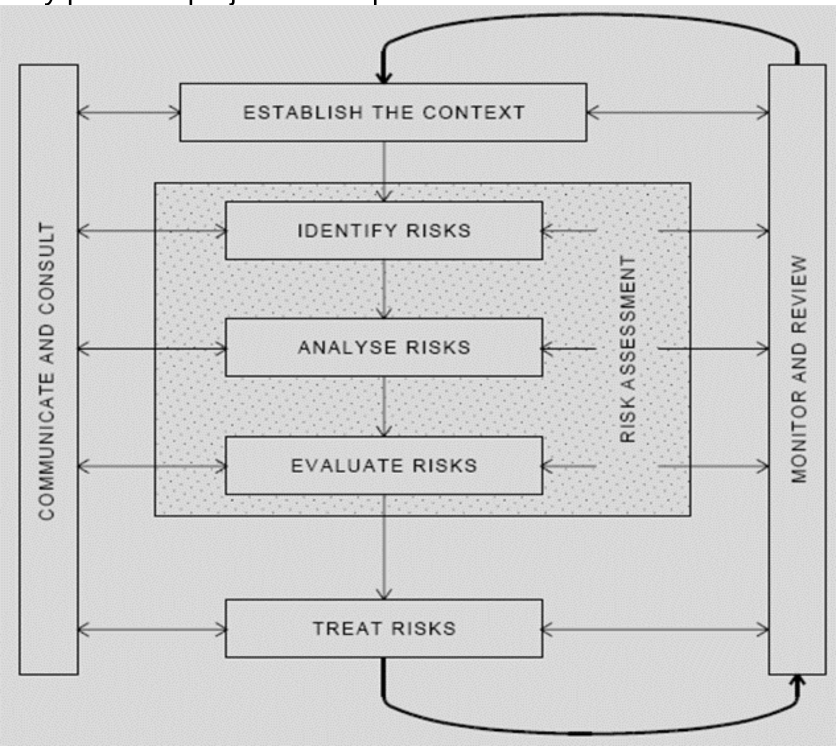



Figure 8-1: Risk Management Framework (AS/NZS 4360:2004 Risk Management)

Shell's HSSE and SP Management System is a system that is continually improving due to incorporation of legislative requirements, changing community expectations, improved available technology, learning from incidents industry wide and within Shell, and regular management review. Assurance that the HSSE and SP Management System is working, continually improving and that each Shell company is correctly applying new Shell standards occurs via local self-assurance and the Shell Global auditing process, which is ongoing and serves to identify gaps and drive gap closure. Company standards are at least equal to, but in many cases more stringent than legislation, and aligned with global good industry practice benchmarks such as those published by the IFC and World Bank. Both legislation and company standards are continually being updated and requiring a higher level of performance over time. Concurrently new technologies are becoming available and making improved performance possible and more affordable. This continual improvement is reflected in more challenging ALARP and tolerable benchmarks, leading to better environmental outcomes over time.

In accordance with the NOPSEMA OPP Guidance Note (NOPSEMA 2018a), the OPP *"must include an evaluation of all the impacts and risks that reaches a conclusion on whether the impacts and risks will be 'acceptable' or 'unacceptable'"*. The demonstration of ALARP is an evaluation criterion relevant to subsequent activity-specific EPs, but is not considered further when evaluating impacts and risks for the purposes of this OPP. At the time of preparing the OPP, project design and execution detail is high level and preliminary, and not sufficiently detailed to perform an ALARP assessment. A much greater level of detail regarding project design and execution will be known during development of activity-specific EPs, at which time an ALARP assessment will be performed.

For the Crux project, the process of identifying and evaluating environmental impacts and risks was derived, at an appropriate level of definition, for a whole-of-project assessment of acceptability at an OPP level. The specific methodology adopted is summarised in the following **Section 8.3**.

## 8.3 Impact Assessment Methodology

This section describes the approach adopted for identifying and assessing impacts and risks on the physical, biological and human environment as relevant to the Crux project. Planned activities give rise to environmental impacts, while unplanned and accidental events pose a risk of environmental impact, if they occur. The risk of environmental impacts resulting from unplanned or accidental events is evaluated by taking the likelihood of the event occurring into consideration.

The approach aligns with Shell's methodology that enables a balanced assessment of planned impacts and unplanned risks, noting that there are some difficulties in relying solely on the Shell Risk Assessment Matrix (RAM) for assessment of significance of potential environmental impacts. Therefore, an adapted methodology has been developed by Shell United Kingdom, for use across Shell Group companies, that ties together both potential 'Magnitude' of a predicted impact and the 'Receptor Sensitivity' as shown in a summary impact significance matrix (see **Section 8.3.2**). The matrix is used for the assessment of impacts for both planned and unplanned events. However, in accordance with the Shell RAM, for assessment of unplanned events, the additional likelihood of occurrence of an event is taken into account.

For the purpose of this assessment, key terminology is defined in **Table 8-1**.

Table 8-1: Definition of Key Terminology for Impact Assessment.

| Term | Definition |
|---|---|
| Activity | Components or elements of work associated with the project. All activities associated with the project have been considered at a broad level (as outlined in **Section 5**). |
| Aspect | Elements of the proponent's activities or products or services that can interact with the environment. These include planned and unplanned (including those associated with emergency conditions) activities. |
| Consequence | The outcome of an event, which can lead to a range of consequences. A consequence can be certain or uncertain and can have positive or negative effects. Consequences can be expressed qualitatively or quantitatively. |
| Control | A measure which mitigates risk through the reduction of the likelihood for a consequence to occur. Controls include existing controls (i.e. Company management controls or industry standards) or additional controls (i.e. additional measures identified during the risk assessment processes). |
| Event | An occurrence of a particular set of circumstances. An event can be one or more occurrences and can have several causes. |
| Factor | Relevant physical, biological, socio-economic and cultural features of the environment. These are also referred to within the OPP as values/sensitivities. |
| Hazard | A substance, situation, process or activity that has the ability to cause harm to the environment. |
| Impact | Any change to the environment, whether adverse or beneficial, wholly or partially resulting from a proponent's environmental aspects. |
| Likelihood | Description of probability or frequency of a consequence occurring with safeguards in place. |
| Inherent risk | The level of risk when existing controls are in place, but before the application of additional risk controls arising from risk assessment processes. |
| Residual risk | The level of risk remaining after risk treatment, i.e. application of additional controls (inclusive of unidentified risk). |
| Acceptable | The level of impact and risk to the environment that may be considered broadly acceptable with regard to all relevant considerations. |

### 8.3.1 Impact Identification and Aspects

The identification of potential impacts is carried out prior to any detailed assessment of the relative importance of each issue, the sensitivity of the existing environmental and/or socio-economic values, or the magnitude of the potential impact, and does not take into account potential mitigation measures.

As summarised in **Section 5.7**, the key project aspects arising from the Crux project have been identified as:

- physical impacts (including vessel movements)
- lighting
- underwater noise
- atmospheric emissions
- IMS
- waste management
- liquid discharges, and
- unplanned spills.

### 8.3.2 Evaluation of Impacts

***Impact Assessment Significance***

The significance of environmental impacts is assessed in terms of:

- magnitude based on the size, extent and duration/frequency of the impact
- the sensitivity of the receiving receptors, and
- the likelihood of an unplanned event occurring.

These are described further below.

***Magnitude***

Levels of magnitude of environmental impacts are outlined in **Table 8-2**. The magnitude of an impact or predicted change takes into account the following (shown descriptively in **Figure 8-2**):

- nature of the impact and its reversibility
- duration and frequency of an impact
- extent of the change, and
- potential for cumulative impacts.

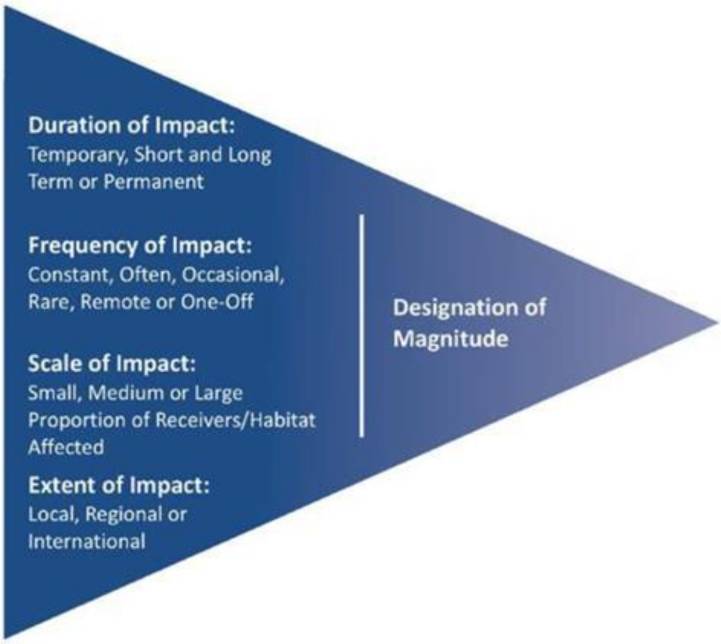



Figure 8-2: Definition of Magnitude in the Context of Impact Identification

The impact magnitude is defined differently according to the type of impact. For readily quantifiable impacts, such as noise or liquid discharge plume extent, numerical values can be used whereas for other topics (e.g. communities and habitats) a more qualitative definition is applicable. These criteria capture high level definitions, adapted as appropriate to the offshore context of the Crux project.

Table 8-2: Magnitude Criteria.

| Definition | Environmental Impact |
|---|---|
| Positive effect | Net positive effect arising from a proposed aspect of the Crux project |
| No effect | No environmental damage or effects |
| Slight effect | Slight environmental damage contained within the project area<br>Effects unlikely to be discernible or measurable<br>No contribution to trans-boundary or cumulative effects<br>Short-term or localised decrease in the availability or quality of a resource, not effecting usage |
| Minor effect | Minor environmental damage, no lasting effects or persistent effects are highly localised<br>Minor change in habitats or species<br>Unlikely to contribute to trans-boundary or cumulative effects<br>Short-term or localised decrease in the availability or quality of a resource, likely to be noticed by users |
| Moderate effect | Moderate environmental damage that will persist or require cleaning up<br>Widespread change in habitats or species beyond natural variability<br>Observed off-site effects or damage, e.g. fish kill or damaged habitats<br>Decrease in the short-term (1–2 years) availability or quality of a resource affecting usage<br>Local or regional stakeholders' concerns leading to complaints<br>Minor trans-boundary and cumulative effects |
| Major effect | Severe environmental damage that will require extensive measures to restore beneficial uses of the environment<br>Widespread degradation to the quality or availability of habitats and/or wildlife requiring significant long-term restoration effort<br>Major oil spill over a wide area leading to campaigns and major stakeholders' concerns<br>Trans-boundary effects or major contribution to cumulative effects<br>Mid-term (2–5 year) decrease in the availability or quality of a resource affecting usage<br>National stakeholders' concern leading to campaigns affecting Company's reputation |
| Massive effect<br>(to be used only for unplanned events) | Persistent severe environmental damage that will lead to loss of use or loss of natural resources over a wide area<br>Widespread long-term degradation to the quality or availability of habitats that cannot be readily rectified<br>Major impact on the conservation objectives of internationally/nationally protected sites<br>Major trans-boundary or cumulative effects<br>Long-term (> 5 year) decrease in the availability or quality of a resource affecting usage<br>International public concern |

### *Receptor Sensitivity*

For this OPP, receptors are categorised into different groups (as described in **Section 6**):

- physical environment – including water quality, sediment quality and oceanography
- threatened species and ecological communities – including marine fauna (marine mammals, marine reptiles, fish, sharks, rays and birds) and associated BIAs, benthic infauna and plankton
- ecosystems, communities and habitats – including shoals/banks, offshore reefs/islands and KEFs, and

- socio-economic and cultural environment – including heritage areas, marine parks, shipwrecks, fishing (commercial, traditional and recreational), tourism and recreation, commercial shipping, and offshore petroleum exploration and operations.

Receptor sensitivity criteria are based on the following key factors:

- importance of the receptor at local, national or international level – for instance, a receptor will be of high importance at international level if it is categorised as a designated protected area (such as a Ramsar site). Areas that may potentially contain high value habitats are of medium importance if their presence/extent have not yet been confirmed
- sensitivity/vulnerability of a receptor and its ability to recovery – for instance, certain species could adapt to changes easily or recover from an impact within a short period of time. Thus, as part of the receptor sensitivity criteria (**Table 8-3**), professional judgement considers immediate or long-term recovery of a receptor from identified impacts. This also considers if the receptor is under stress already, and
- sensitivity of the receptor to certain impacts – for instance, flaring emissions will potentially cause air quality impacts and do not affect other receptors such as seabed.

Table 8-3: Receptor Sensitivity Criteria

| Sensitivity | Definition |
|---|---|
| Low | Receptor with low value or importance attached to them, e.g. habitat or species which is abundant and not of conservation significance, or<br>Immediate recovery and easily adaptable to changes |
| Medium | Receptor of importance, e.g. recognised as an area/species of potential conservation significance for example, KEF or listed threatened species, or<br>Recovery likely within 1–2 years following cessation of activities, or localised medium-term degradation with recovery in 2–5 years. |
| High | Receptor of key importance, e.g. recognised as an area/species of potential conservation significance with development restrictions for example marine parks or conservation reserves, or habitat critical to the survival of a species, or<br>Recovery not expected for an extended period (> 5 years following cessation of activity) or that cannot be readily rectified |

### *Significance Criteria for Planned Events*

The magnitude of the impact and sensitivity of receptor is then combined to determine the impact significance as shown in **Table 8-4**. Key management controls are subsequently identified to reduce the potential for such an event occurring in order to determine residual impact and inform an assessment of acceptability.

Table 8-4: Impact Significance Matrix (Planned)

| | | Sensitivity | | |
|---|---|---|---|---|
| | | **Low** | **Medium** | **High** |
| **Magnitude** | **+1 - Positive** | Positive effect | Positive effect | Positive effect |
| | **0 – No effect** | No effect | No effect | No effect |
| | **1 - Slight effect** | Slight | Slight | Minor |
| | **2 – Minor effect** | Minor | Minor | Moderate |
| | **3 – Moderate effect** | Minor | Moderate | Major |
| | **4 – Major effect** | Moderate | Major | Major |

### *Unplanned Events (Likelihood Criteria)*

For unplanned events the likelihood of such an event occurring also requires consideration. For example, based on magnitude and sensitivity alone a hydrocarbon spill associated with a long-term well blowout would be classed as having major impact significance, however, the likelihood of such an event occurring is very low. In addition, the mitigation measures for such impacts focus on reducing the likelihood of the impact occurring as opposed to reducing the effects of the impact itself. Thus, unplanned events also require assessment in terms of environmental risk.

As with planned activities, the potential impacts of unplanned events are identified, and the impact significance is determined, which inherently takes into account the sensitivity of the relevant receptor(s). The significance of the impact will then be combined with the likelihood of the event occurring (**Table 8-5**) in order to determine its overall environmental risk as summarised in **Table 8-6**. Key management controls are then identified to reduce the risk of such an event occurring in order to determine residual risk and inform assessment of acceptability.

Table 8-5: Likelihood Criteria

| Likelihood | Definition |
|---|---|
| A | • Never heard of in the industry – extremely remote<br>• < $10^{-5}$ per year<br>• Has never occurred within the industry or similar industry but theoretically possible |
| B | • Heard of in the industry – remote<br>• $10^{-5}$ – $10^{-3}$ per year<br>• Similar event has occurred somewhere in the industry or similar industry but not likely to occur with current practices and procedures |
| C | • Has happened in the Company or more than once per year in the industry – unlikely<br>• $10^{-3}$ – $10^{-2}$ per year<br>• Event could occur within lifetime of similar facilities. Has occurred at similar facilities |
| D | • Has happened at the location or more than once per year in the Company – possible<br>• $10^{-2}$ – $10^{-1}$ per year<br>• Could occur within the lifetime of the development |
| E | • Has happened more than once per year at the location – likely<br>• $10^{-1}$ – > 1 per year<br>• Event likely to occur more than once at the facility |

Table 8-6: Environmental Risk Matrix (Unplanned Events)

| | | Likelihood | | | | |
|---|---|---|---|---|---|---|
| | | **A** | **B** | **C** | **D** | **E** |
| Impact Significance | **No effect** | No effect | | | | |
| | **Slight** | Negligible | Negligible | Minor | Minor | Minor |
| | **Minor** | Negligible | Minor | Minor | Moderate | Moderate |
| | **Moderate** | Minor | Minor | Moderate | Moderate | Major |
| | **Major** | Moderate | Moderate | Moderate | Major | Major |
| | **Massive** | Major | Major | Massive | Massive | Massive |

For the purpose of the Crux risk review, the following key risks were assessed in accordance with the risk-based approach summarised in this section:

- vessel movements, in the context of unplanned interactions with marine fauna
- IMS
- unplanned (spill) events, and
- unplanned release of off-specification PFW.

### 8.3.3 Assessment of Residual Impacts and Risks

The iterative impact assessment process takes into account the mitigation measures that have been adopted as part of the project design and project plan. As such each impact will be re-assessed taking mitigation measures, controls and safeguards into account in order to determine the residual impact (or risk for unplanned events). In the evaluation of residual impacts and risks, all controls are assumed to be implemented effectively and functioning as intended.

The residual impact detailed in **Section 8.4** represents a summary of the various individual environmental value/sensitivity rankings defined from a detailed environmental risk workshop attended by specialist environmental scientists together with key members of the Shell project team who are directly responsible for the design and development the Crux project. The residual impact rankings provided represent the highest residual impact for that receptor group (i.e. physical environment, threatened species and ecological communities, ecosystems, communities and habitats, and socio-economic and cultural environment), and therefore may be a conservative assessment for some individual environmental values/sensitivities.

### 8.3.4 Environmental Performance Outcomes

Environmental Performance Outcomes (EPOs) have been developed for all aspects of the Crux project. The purpose of the EPOs is to provide specific, measurable levels of environmental performance that are:

- consistent with the principles of ESD, and
- demonstrate that the environmental impacts and risks of the Crux project are of an acceptable level.

Note that the consideration of acceptability for each aspect is provided in the relevant **Acceptability** sections in the evaluation of environmental impacts and risks. Consequently, these acceptability considerations are a component of the EPO.

The EPOs in this OPP will be inherited by the subsequent EPs for petroleum activities conducted within the scope of the OPP. Given the relatively early stage of technical definition (i.e. pre-FEED) phase of the Crux project, the EPOs in the OPP may not be inherited verbatim on subsequent EPs, however any EP EPOs will maintain the equivalent, or better, level of environmental performance.

EPOs provided in this OPP will be demonstrated through the implementation of subsequent EPs. EPOs associated with planned impacts will generally be demonstrated through successful implementation of controls, environmental performance standards and associated measurement criteria. Note that control may include environmental monitoring programs, however these are not required where there is high confidence in the effectiveness of controls and the potential for environmental impact is low. Where an unplanned event (e.g. accidental discharge) results in the potential for environmental harm, the incident reporting and investigation process will identify if there is the potential for environmental impacts. This process will provide sufficient information to determine if the EPO has not been achieved.

Considering the ongoing concept refinement and remaining front end engineering work required to be completed, key controls outlined in this **Section 8** are all considered to be initial judgements on likely available key controls, however where a control relates to elements of operations or design yet to be established, it should be recognised that adjustments in what these key controls end up being established may change, subject to final design and operational processes established. It should also be recognised that all environmental impacts and risks will be managed to acceptable levels on an ongoing basis.

## 8.4 Evaluation of Project Environmental Impacts and Risks

### 8.4.1 Physical Presence and Vessel Movements

#### 8.4.1.1 Project Context

Aspects of the Crux project will result in a physical presence in the marine environment, which may interact with environmental receptors. These aspects are described in **Section 5.7.1** and include:

- drilling the foundation wells with a moored semi-submersible rig
- installation, operation and decommissioning of the Crux platform (jacket structure)
- installation, operation and decommissioning of the export pipeline and subsea integration system (e.g. Crux PLET and Prelude PLET)
- completion, operation and abandonment of wells
- potential future subsea facilities associated with well and tie-back infrastructure, and
- vessel operations associated with the above points, including potential mooring within the in-field development area.

A petroleum safety zone of 500 m will be established around the Crux platform, as per the OPGGS Act, from which unauthorised marine users will be excluded. The petroleum safety zone is a key safety measure to reduce potential interactions with the Crux platform and associated subsea infrastructure. Temporary exclusion zones will be maintained around any drilling rigs and the pipelay vessel.

Refer to **Section 5.7.1** for additional information on these aspects.

The proposed direct seabed disturbance for the Crux project are summarised in **Table 5-4**.

#### 8.4.1.2 Description and Evaluation of Impacts and Risks

A range of environmental sensitivities within the following groups may be impacted by the physical presence of the Crux project, including:

- physical environment
- ecosystems, communities and habitats
- threatened species and ecological communities, and
- socio-economic and cultural environment.

Potential impacts and risks associated with aspects of the Crux project with these are discussed below. As outlined in **Section 8.3.3**, the assessment considers only the residual impacts and risks following the application of controls.

**Physical Environment**

*Bathymetry and Seabed Features*

Extensive seabed surveys of the Crux project footprint have been carried out in 2017 (e.g. Fugro 2017a, 2017b), which indicate the seabed is relatively flat with a gentle gradient, with one area of outcropping reef identified in the north-eastern portion of the in-field development area (**Figure 6-4**). Sediments within the project area are typically smooth and bare, with sediment particle size distribution characterised by sand particles (muddy sands at the western end of the pipeline corridor, transitioning to gravelly sands at the proposed location of the Crux platform).

Activities associated with the drilling and installation of wells will result in physical disturbance of the seabed via the deployment and retrieval of drilling rig anchors and mooring lines. Seabed disturbance from anchoring is localised to the footprint of the mooring spread, which is estimated to cover an area of approximately 10,000 $m^2$ for the foundation development drilling program. A mooring may also be installed within the Crux in-field development area for use during the project and will have a much smaller area of seabed disturbance. A small footprint of disturbed seabed will remain (e.g. pull-out scar or mound) following anchor recovery. This footprint is expected to be subject to natural sedimentary processes and will result in slight seabed disturbance contained entirely within the project area.

Drilling will also result in the discharge of cuttings to the marine environment. The environmental impacts and risks associated with the discharge of drill cuttings are provided in **Section 8.4.8**.

Installation of the Crux platform will result in modification of the seabed in the immediate area surrounding the jacket piles. The jacket piles will provide hard substrate, which is likely to lead to the development of associated biological communities and increase the potential for localised scouring. This disturbance will persist while the platform jacket is in place. Seabed disturbance from the construction and operation of the Crux platform will result in a slight effect to bathymetry and seabed features, which will be highly localised to the seabed immediately around the platform.

Installation of the export pipeline will modify the habitat directly below the pipeline, with the existing unconsolidated sediments replaced by hard substrate (i.e. the pipeline). Given the nature of the sediments within the pipeline corridor, it is expected that sections of the pipeline may become buried over time because of natural sediment movement, resulting in the return of soft sediment habitat. No pipeline rock stabilisation or trenching is planned during installation of the export pipeline.

Localised scour and/or pipeline movement may also occur and potentially result in free spans that require rectification or stabilisation (e.g. installation of grout bags, concrete mattresses, localised jetting using a remotely operated vehicle etc.). The disturbance from rectification and stabilisation activities is expected to be highly localised to discrete areas of the export pipeline. The footprint on the seabed of grout bags on the seabed is typically confined to a small area directly below the pipeline. The footprint of a grout bag is a consequence of the size of the bag. Bag size selection typically depends on the size of the span that requires rectification; larger spans typically require larger bags; most have a footprint < 100 $m^2$. The footprint of a mattress depends on the size of the mattress being used; typical mattresses cover approximately 100 $m^2$. Mattress size selection is dependent on the scale of the span or stabilisation required. While the need for grout bags or mattresses (if any) is currently unknown, operational experience indicates they are not typically required in large numbers given the export pipeline will have a concrete weight coating.

Installation of the subsea integration system and associated subsea facilities (including for any future tiebacks) in the in-field development area will consist of infrastructure such as a PLET, manifold, flowlines, spools and potentially subsea compression, where this a preferred concept in future. The footprint associated with these subsea components will be highly localised.

While not intended, objects such as tools and equipment may be dropped during the project from the Crux platform or project vessels. Any seabed disturbance associated with dropped objects will be within the project area and limited to a very localised footprint in the immediate vicinity of the contact with the seabed.

The preferred decommissioning option of the Crux platform and export pipeline have not yet been selected and will depend on a range of factors. If decommissioning in situ is undertaken, the modification of the seabed by the decommissioned infrastructure will effectively be long term (i.e. many decades to potentially hundreds of years) before reverting to a condition consistent with the natural seabed. The infrastructure remaining in situ will provide the basis for artificial reefs.

*Water Quality*

Impacts to water quality from the physical presence of the Crux project are expected to be restricted to localised sediment plumes during deployment and recovery of drilling rig anchors and installation of the export pipeline, platform and subsea integration system. Sediment plumes from these activities may result in a slight and temporary decrease in water quality due to increase in suspended sediments. These slight, temporary impacts to water quality will not impact biodiversity or ecological integrity within the Crux project area.

*Sediment Quality*

Impacts to sediment quality from physical presence during all phases of the Crux project are expected to be minor. Changes to physical properties, such as particle size distribution and geological origin, are not expected to occur beyond the immediate footprint of the subsea infrastructure. These changes will not impact biodiversity or ecological integrity within the Crux project area.

The discharge of drill cuttings may result in changes to sediment quality; the environmental impacts and risks from the discharge of drill cuttings are considered in **Section 8.4.8**.

Other liquid discharge streams (e.g. liquid discharges such as produced water, sewage and putrescible waste) and unplanned releases of solid waste may also impact sediment quality. Waste management and liquid discharges, and the associated environmental impacts and risks, are discussed in **Sections 8.4.7** and **8.4.8** respectively.

**Ecosystems, Communities and Habitats**

*Benthic Communities*

Surveys of the project area identified several benthic communities, which were closely associated with seabed characteristics (Fugro 2017a).

Much of the project area comprises unconsolidated sediments, with the characteristics of the sediment influencing benthic communities (**Section 6.4.2**). Coarser sediments (e.g. higher gravel or sand fractions) appeared to support sparse assemblages of filter (e.g. sea pens and sponges) and deposit feeders (e.g. urchins). Sediments with a relatively high portion of muds tended to host burrowing (e.g. polychaete worms, bivalve molluscs, crustaceans) and deposit feeding organisms (e.g. urchins, sea cucumbers). These benthic communities were observed at low densities. The habitats associated with these communities are broadly distributed in the wider region and are not considered to be unique or highly sensitive. The installation infrastructure associated with the Crux project (including stabilisation or span rectification using grout bags or mattresses or jetting with a remotely operated vehicle) will result in the disruption of a relatively small area of soft sediment habitats, which will become hard substrate habitats due to the presence of subsea infrastructure. The potential impacts and risks to these communities from the physical presence of the Crux project are considered to be minor and do not exceed the significant impact criteria for the Commonwealth marine environment listed in **Table 7-1**.

Relatively small areas of hard substrate were observed in the in-field development area, and a small portion of the export pipeline corridor. The hard substrate in the in-field development area consists of an outcropping reef feature, which forms part of an extensive seabed ridge, with benthic habitats comprising filter feeders, some corals and burrowing macrofauna (**Figure 6-8**). The area of hard substrate observed within the export pipeline corridor comprised a relatively small portion of benthic habitats in the area, and was characterised by hydroids, sponges and branching corals (Fugro 2017a). This area overlaps the continental slope demersal fish communities KEF (refer to **Key Ecological Features** below).

*Shoals and Banks*

There are three shoals within the in-field development area; Goeree Shoal, Eugene McDermott Shoals and Vulcan Shoal. These will not be directly impacted by the physical presence of the Crux project as Shell will apply a 1 km buffer around such features (refer to the blue box titled **Will a One Kilometre Buffer Protect the Shoals?** below for further information). This buffer is expected to be sufficient to avoid direct and indirect impacts and risks from the physical presence of the Crux project. The potential impacts and risks to shoals and banks from the physical presence and vessel movements aspect of the Crux project are expected to result in no direct impacts on the shoals within (i.e. Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal) or beyond the Crux in-field development area.

**Will a One Kilometre Buffer Protect the Shoals?**
The shoals and banks in the Timor Sea are features that are "islands" of notable biodiversity, hosting benthic habitats and communities that are of high environmental value (refer to **Section 6.4.4**). Three shoals are situated within the Crux in-field development area: Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal. The nearest of these shoals (Goeree Shoal) is approximately 13 km from the Crux platform. Shell will implement a 1 km buffer around the outer boundary of these shoals within which no project activities will take place. The outer boundary of the shoals is considered to be defined by the 50 m water depth contour, as extracted from the Geoscience Australia 250 m resolution bathymetry data. This depth contour is considered appropriate in the context of the benthic habitat mapping undertaken for the shoals within the Crux in-field development area, as presented in **Section 6.4.4** of the OPP

Shell recognises the high environmental value of these shoals, and has situated the Crux platform and export pipeline corridor away from these features to reduce the potential for environmental impacts. As a result, Shell is confident the foundation development drilling, Crux platform construction, export pipeline installation, operations and decommissioning will have no direct impacts on the banks and shoals in the Crux project area.

The scope of this OPP also includes future tieback wells in the Crux in-field development area. The locations of future tieback wells has not yet been determined, and they may occur in proximity to Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal. Shell recognises that the drilling of these wells may result in environmental impacts and risks to the habitats and communities of these shoals from:

- Physical presence and vessel movements:
  - installation, use and removal of the anchoring spread for the MODU
  - presence of support vessels
- Liquid discharges:
  - discharge of drilling fluids and cuttings
  - utility discharges from the drilling rig and support vessels (e.g. sewage, putrescible wastes etc.)
- Underwater noise:
  - underwater noise emissions from VSP
  - underwater noise from support vessels
- Unplanned spills:
  - loss of well control
  - loss of vessel fuel.

Shell has evaluated the environmental impacts and risks from these activities. Based on the outcomes of this evaluation, Shell has committed to implementing a 1 km buffer around the outer boundaries of each of these shoals within which no activities associated with the Crux project will take place. The reasoning for the 1 km buffer for each of the aspects listed above is provided below.

**Physical Presence and Vessel Movements**
The risks and impacts from physical presence and vessel movements to the benthic habitats and communities of the shoals occur within the direct footprint of these activities. The 1 km buffer ensures the footprint of any future tieback drilling is well beyond the shoals, resulting in no impacts.

**Liquid Discharges**
Shell has undertaken numerical modelling studies of the discharge of drilling fluids and cuttings to inform the assessment of potential impacts and risks (refer to **Section 8.4.8**). This assessment concluded the low impact threshold (1 mm) for sediment deposition would be reached within < 326 m, and be consistent with natural levels within < 2 km. Given the MODU will be moored in place using anchors (which must be outside the 1 km buffer), and the horizontal distance between anchors and the MODU is approximately > 1,000 m for the waters depths in the Crux in-field development area, the discharge point for drilling fluids and cuttings will be well beyond the 1 km buffer. This ensures that sediment deposition is well below impact thresholds beyond the shoals.

The discharge of drilling fluids and cuttings will result in a plume of increased suspended sediments, which may move towards a shoal, depending on prevailing currents. Given the distance between the discharge location and the shoals, this plume has little potential to impact upon the benthic habitats and communities (refer to **Section 8.4.8** for further discussion).

Utility discharges from the MODU and support vessels will mix rapidly and will not result in impacts beyond the discharge point.

**Underwater Noise**
Modelling of underwater noise levels for VSP indicated that noise levels would not exceed the permanent injury, temporary threshold shift and behavioural impact thresholds at any range. Noise from

**Unplanned Spills**
Unplanned spills such as loss of well control, have the potential to impact large areas, and a worst-case loss of well control from any location within the Crux in-field development area is likely to have potential imapcts on shoals. A 1 km buffer is not effective in preventing impacts from a loss of well containment. Shell applies its considerable resources and experience in ensuring that such large-scale hydrocarbon releases during during drilling do not occur.

*Key Ecological Features*

The continental slope demersal fish communities KEF is partially overlapped by the export pipeline corridor, with the corridor covering approximately 14 $km^2$ (less than 0.05%) of the KEF. No other components of the project area overlap this KEF. Environmental surveys of the export pipeline corridor did not observe particularly high or diverse fish assemblages within the overlap, although isolated areas of hard substrates and associated communities were observed (Fugro 2017a). The installation of the export pipeline may result in disturbance to benthic communities within the KEF. The presence of pipelines has been positively correlated with the diversity and abundance of fish (McLean et al. 2017); over time, the export pipeline is expected to host an artificial reef community with relatively high fish diversity and abundance compared to the surrounding seabed.

Given the ecological value of the continental slope demersal fish communities KEF is the relatively high diversity of demersal fish species, physical presence of the export pipeline is not expected to have any impact on the environmental value of the KEF. Subsea infrastructure construction has not been identified as an actual or potential concern in relation to the KEF (DSEWPaC 2012b). No other KEFs overlap the project area.

**Threatened Species and Ecological Communities**

*Key Fauna Species*

Project vessels moving in the project area may present a hazard to protected marine fauna, such as whales, turtles and whale sharks. Vessel movements can result in collisions between the vessel and marine fauna, potentially resulting in injury or death. Factors affecting the likelihood and severity of impacts from collisions include vessel type, vessel speed, water depth and the behaviours of animals present (Commonwealth of Australia 2017c). The risks of vessel collisions with marine fauna, particularly threatened and migratory species (i.e. MNES), described below are consistent with the acceptable levels of impacts defined in **Section 7**. Shell's environmental management of the physical presence and vessel movements aspect of the Crux project is aligned with conservation advice, recovery plans and threat abatement plans published by the DoEE; refer to discussion of MNES in the discussion of Acceptability below (**Section 8.4.1.4**).

Whales are vulnerable to collisions with vessels due to their large size and the relatively high proportion of time spent at or near the sea surface. The likelihood and consequence of vessel collisions with whales are influenced by vessel speed; the greater the speed at impact, the greater the risk of mortality (Jensen and Silber 2004; Laist et al. 2001). Vanderlaan and Taggart (2007) found that the chance of lethal injury to a large whale as a result of a vessel strike increases from about 20% at 8.6 knots to 80% at 15 knots. According to the data of Vanderlaan and Taggart (2007), it is estimated that the risk is less than 10% at a speed of 4 knots. Vessel-whale collisions at this speed are uncommon and, based on reported data contained in the United States National Ocean and Atmospheric Administration (NOAA) database (Jensen and Silber 2004), there only two known instances of collisions when the vessel was travelling at less than 6 knots. Both of these were from whale watching vessels that were deliberately placed amongst whales.

Project vessels within the project area, carrying out petroleum activities, are likely to be travelling less than 8 knots; much of the time vessels are holding station or moving very slowly (e.g. pipelay vessels typically move < 1–2 knots, laying up to 2 km of pipe per day). Therefore, the risk of a vessel collision with whales is inherently low. No known key aggregation areas for whales (resting, breeding, migration or feeding) are located within or immediately adjacent to the project area. The nearest recognised BIAs for cetaceans is the pygmy blue whale migration area, which lies approximately 69 km west of the project area. Shell acknowledges that the BIA is indicative only, and that blue whales may be present beyond the boundary of the BIA.

Whale sharks are at risk from vessel strikes when feeding at the surface or in shallow waters (where there is limited option to dive). Whale sharks occur within the project area (e.g. traversing the open waters within or surrounding the project area during migration to and from aggregation off Ningaloo Reef) and a BIA for whale sharks overlaps with the project area. However, it is expected that whale shark presence within the project area would not comprise of significant numbers given there is no main aggregation area within the vicinity of the project area, and their presence would be transitory and of a short duration. This is consistent with tagging studies of whale shark movements which show continual movement of whale sharks in deeper, open offshore waters (Meekan and Radford 2010). There are no constraints preventing whale sharks from moving away from vessels (e.g. shallow water or shorelines).

The project area is unlikely to represent important habitat for marine turtles given the absence of potential nesting. Much of the project area is in water depths > 90 m, which is deeper than typical foraging dives by marine turtles (e.g. Hays et al. 2001; Polovina et al. 2003), although there are three named shoals that rise to approximately 30 m water depth. Shell has established a 1 km exclusion zone around these shoals (**Figure 5-3**). As such, the presence of marine turtles within the project area is likely to be restricted to individual turtles transiting the area, with potential foraging at the relatively shallow shoals in the in-field development area. No BIAs or habitat critical for the survival of marine turtles, as identified in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017b), overlap the project area. As with cetaceans, the risk of collisions between turtles and vessels increases with vessel speed (Hazel et al. 2007). The typical response from turtles on the surface to the presence of vessels is to dive (a potential “startle” response), which decreases the risk of collisions (Hazel et al. 2007). Given the low speeds of project vessels, along with the expected low numbers of turtles within the project area, interactions between vessels and turtles are highly unlikely.

Given the offshore location and distance to the closest shorelines (approximately > 100 km from the Crux platform), the number of birds within the project area is expected to be low. No BIAs for birds overlap the project area. The Crux platform may eventually provide roosting habitat for seabirds, which may be attracted to the platform. The presence of birds can lead to damage of the platform (e.g. guano fouling of equipment). Shell may install non-lethal bird deterrents (e.g. acoustic deterrents) to reduce the attractiveness of the platform for birds. Such deterrents are routinely used throughout the world to prevent damage to offshore platforms. Birds may also be attracted to vessels, resulting in a temporary behavioural disturbance. The potential behavioural disturbance resulting from the physical presence of the Crux project is slight.

Fish species, particularly site attached species, will be attracted to the Crux platform and subsea infrastructure, which will function as an artificial reef. As outlined above in the discussion of benthic communities, the physical presence of the Crux project infrastructure is expected to have a slight positive effect on fish species diversity and abundance resulting from the creation of an artificial reef in an area which consists primarily of soft, unconsolidated sediments.

**Socio-economic and Cultural Environment**

*Marine Archaeology*

A review of the ANSD did not identify any known shipwrecks within the project area. Bathymetric surveys of the project area did not identify any seabed features consistent with wrecks or archaeological features. As such, no impacts to marine archaeological values will occur as a result of the project.

*Commercial Fishing*

Several State- and Commonwealth-managed commercial fisheries overlap the project area (**Section 6.6.9**). However, only the Commonwealth managed North-West Slope Trawl Fishery and the State managed Northern Demersal Scalefish Managed Fishery are active near the project area. Potential impacts and risks from physical presence of the Crux project include temporary displacement of commercial fishers (primarily during the installation phase) and the permanent exclusion of commercial fishers from the 500 m petroleum safety zone surrounding the Crux platform. There have been no concerns from commercial fishers regarding the presence of the Shell Prelude FLNG facility and associated exclusion area, which is 165 km south-west of the Crux platform.

Most historical fishing effort in the Commonwealth-managed NWSTF lies beyond the project area, with the majority of fishing occurring south-east of Scott Reef. The fishery primarily targets scampi using demersal trawls. The export pipeline corridor is the only element of the project area that overlaps the NWSTF managed area, with the overlapping area (approximately 233 km$^2$) representing less than 0.06% of the managed fishery area. Historical effort in the NWSTF lies primarily to the south-west of the project area (**Section 6.6.9**), with little recorded effort in the immediate vicinity of the project area. Effort in the fishery is relatively low, with one to two vessels active in the fishery in the 2014–15 and 2015–16 fishing seasons (Woodhams and Bath 2017). Given the fishing method (demersal trawls) may interact with infrastructure on the seabed, there is the potential for interactions such as gear entanglement. Participants in the fishery may also be temporarily displaced by vessels during installation of the export pipeline. This potential is considered very low given:

- the location of all subsea infrastructure will be provided to the Australian Hydrographic Office for inclusion on nautical charts
- prior to formal consultation and release of this document, Shell's targeted and ongoing consultation program has not as this stage identified any concerns from participants in the NWSTF, and
- the relatively small project footprint and the lack of fishing effort near the project area.

The project area partially overlaps Zones B and C of Area 2 (offshore area) of the State-managed Northern Demersal Scalefish Managed Fishery. Zone B contains most activity in the fishery, with Zone C representing a developing deep-water fishery area (Department of Fisheries 2017). The fishery in Zones B and C is primarily a trap-based fishery, with some line fishing. The in-field development area overlaps approximately 146 km$^2$ of Zone B (approximately 0.2%); the export pipeline corridor overlaps approximately 62 km$^2$ and 252 km$^2$ of Zones B (approximately 0.08%) and C (approximately 0.34%) respectively. The petroleum safety zone exclusion represents less than 0.01% of Zone B of the Northern Demersal Scalefish Fishery. The fishery is active, with seven vessels participating in the Northern Demersal Scalefish Fishery in

2015 (Department of Fisheries 2017). Given the fishery does not use trawls, the chance of gear entanglement with subsea infrastructure is very unlikely. Entanglement of set fishing gear (e.g. traps) with project vessels and equipment is also considered unlikely. Participants in the Northern Demersal Scalefish Fishery may temporarily be displaced by project vessels and the drilling rig, and permanently excluded from the 500 m petroleum safety zone around the Crux platform. Once installed, the subsea infrastructure (predominantly the export pipeline) may enhance targeted fish stocks by functioning as an artificial reef. The impacts and risks of exclusion/displacement from areas of the managed fishery from the Crux project are slight.

*Traditional Indigenous Fishing*

The export pipeline corridor partially overlaps the MoU box, within which traditional Indonesian fishing is permitted. These fishing activities are restricted to relatively shallow waters, such as waters surrounding Ashmore Reef, Cartier Island, Seringapatam Reef, Scott Reef and Browse Island. The export pipeline corridor does not include any shallow seabed features that may be targeted by traditional Indonesian fishers. The potential impacts and risks from the physical presence of the Crux project are considered to result in no effect on traditional fishing.

*Ports and Commercial Shipping*

Vessel tracking data from the AMSA indicates that commercial shipping in the project area is negligible, with the exception of support vessels at the existing Prelude FLNG facility and the Montara development. Potential impacts and risks to commercial shipping include temporary displacement from around project vessels and the drilling rig (primarily during the installation phase) and exclusion from the petroleum safety zone surrounding the Crux platform. The potential impacts and risks from the physical presence of the Crux project are considered to result in no effect on ports and commercial shipping.

#### 8.4.1.3 Risk and Impact Summary and Key Management Controls

Table 8-7: Physical Presence and Vessel Movements Evaluation of Impacts and Risks

| **Project Component/ Activity** | **Environmental Value/Sensitivity** | | | | **Evaluation – Planned** | | |
|---|---|---|---|---|---|---|---|
| | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Magnitude** | **Sensitivity** | **Residual Impact** |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from the physical presence of the Crux project, including:<br>• drilling of the foundation wells with a moored semi-submersible drilling rig<br>• physical presence of the Crux platform, export pipeline and subsea integration system,<br>• presence of project vessels and vessel movements, and | | X | X | X | Minor effect | Low | Minor |

| Project Component/ Activity | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Significance | Likelihood | Residual Risk |
|---|---|---|---|---|---|---|---|
| • seabed disturbance from project footprint. | | | | | | | |
| **Evaluation – Unplanned** | | | | | | | |
| **Project Component/ Activity** | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Significance** | **Likelihood** | **Residual Risk** |
| Unplanned risks resulting from the physical presence of the Crux project, including: <br>• presence of project vessels and vessel movements – collision with marine fauna. | | X | | | Minor | Unlikely | Minor |

***Key Management Controls***

All project vessels operating within the project area will adhere to the navigation safety requirements contained within the International Regulations for Preventing Collisions at Sea 1972 (COLREGS), Chapter 5 of The International Convention for the Safety of Life at Sea 1974 (SOLAS Convention), International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention), the *Navigation Act 2012* and any subsequent Marine Orders, which specify standards for crew training and competency, navigation, communication, and safety measures.

Maintenance of a minimum 1 km buffer from shoals within the in-field development area (**Figure 5-3**).

Vessels will adhere to the requirements of the EPBC Regulations Part 8.1 – Interacting with cetaceans, (except in emergency conditions or when manoeuvring is not possible, such as in the case of pipelay activities), which include:

- implement a caution zone of 150 m for dolphins and 300 m for whales
- vessels will not knowingly approach closer than 100 m to a whale and 50 m for a dolphin (i.e. no approach zone)
- make sure a vessel does not drift or approach within 50 m of a dolphin or 100 m of a whale
- vessels will not knowingly travel > 6 knots within the caution zone of a whale or dolphin, and
- there will not knowingly be no more than three vessels within 300 m of a whale (i.e. caution zone).

All areas of the seabed disturbed by installation activities will be surveyed prior to installation. (The Crux NNM platform location and export pipeline corridor have been surveyed as part of the baseline environmental studies for the Crux project and no sensitive seabed features were observed).

Validate that the Crux platform, export pipeline and subsea integration system facilities are laid according to planned locations within allowable tolerances.

An anchoring plan will identify suitable areas for anchors to be placed within the in-field development area and will confirm no anchoring on shoals or within the associated 1 km buffer.

If future tie-backs are proposed within 2 km of the shoals or on the outcropping reef feature within the Crux in-field development area, then additional studies will be undertaken to further characterise the benthic habitats within the proposed disturbance area. The studies will inform an assessment of the acceptability of the impacts, particularly with regard to disturbance of any hard seabed substrates that contain high biodiversity value.

Australian Hydrographic Service will be advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners.

*Decommissioning*

Development and implementation of a project decommissioning plan which considers environmental impacts and risks.

Prior to the end of operating life, a comparative assessment of potential decommissioning options will be undertaken to inform the development of a Decommissioning EP that will be submitted to

NOPSEMA. The comparative assessment will consider the merits of each option in the context of health, safety and environmental protection, technological feasibility, local capacity, regulatory compliance, public participation and economic stewardship within a broader ALARP framework to inform selection of the preferred decommissioning strategy.

The Decommissioning EP will present the outcomes of the comparative assessment and include an ALARP and acceptability assessment of the preferred option. The acceptability assessment will consider ESD, industry standard at the time and stakeholder expectations. The Decommissioning EP will be implemented for the duration of the decommissioning activities.

#### 8.4.1.4 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the physical presence and vessel movements aspect of the Crux project are summarised in **Table 8-8**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the physical presence and vessel movements aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the physical presence and vessel movements aspect of the Crux project is provided below.

Table 8-8: Acceptable Levels of Impacts and Risks from Physical Presence and Vessel Movements

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Physical Environment | Water quality | No significant impacts to water quality during the Crux project. | Yes, no significant impacts are expected as a result of physical presence and vessel movements, given the localised disturbance from these activities.<br>These slight, temporary impacts to water quality will not impact biodiversity or ecological integrity within the Crux project area. |
| | Sediment quality | No significant impacts to sediment quality during the Crux project. | Yes, no significant impacts are expected as a result of physical presence and vessel movements, given the localised disturbance from these activities.<br>These slight, temporary impacts to sediment quality will not impact biodiversity or ecological integrity within the Crux project area. |
| Ecosystems, Communities and Habitats | Benthic communities | No significant impacts to benthic habitats and communities.<br>Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | Yes, no significant impacts are expected, given the development footprint represents a small portion of a large regional benthic environment. Habitats associated with these communities are broadly distributed in the wider region and are not considered to be unique or highly sensitive. The outcropping reef feature, which intersects the Crux in-field development area, forms part of an extensive seabed ridge and surveys suggest this feature does |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| | | | not support highly diverse benthic communities, such as those characteristic of shoals and banks within the region. Impacts to non-sensitive communities is estimated to be < 0.1% of the total project area which is much less that the acceptable level of impact for benthic communities. This value accounts for uncertainty in the predicted seabed disturbance expected during the foundation project and any future tie-backs given the early stage of the project development. |
| | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of coral communities at named banks or shoals as a result of indirect/offsite[5] impacts associated with the Crux project. | Yes, the application of a 1 km buffer around the shoals will ensure that there are no direct impacts as a result of physical presence or vessel movements. This buffer will also achieve the acceptable environmental level of no loss of coral communities from indirect impacts. |
| | Key Ecological Features | No significant impacts to environmental values of KEFs. | Yes, no significant impacts are expected as a result of physical presence or vessel movements, given the project footprint only overlaps less than 0.05% of the continental slope demersal fish communities KEF. No other KEFs overlap the project area. |
| Threatened Species and Ecological Communities | Key fauna species | No mortality or injury of threatened or migratory MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory MNES fauna. | Yes, project impacts and risks are of an acceptable level, given the Crux project is not located in any BIAs or habitat critical to the survival of a species, with the single exception of the BIA for the whale shark, which represents a broad migratory corridor. Given the low speeds of project vessels, along with the expected low numbers of marine fauna within the project area, interactions between vessels and MNES fauna are unlikely.<br>Shell's environmental management of the physical presence and vessel movements aspect of the Crux project is aligned with conservation advice, recovery plans and threat abatement plans. |

[5] As defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoEE 2013).

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Socio-economic and Cultural Environment | Commercial fisheries | No negative impacts to exploited fisheries resource stocks which result in a demonstrated direct loss of income.<br>Temporary displacement of commercial fishing activities within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of commercial fishing activities from gazetted petroleum exclusion zones is acceptable. | Yes, project impacts and risks are of an acceptable level, given commercial fishing is typically concentrated mostly in coastal waters and little fishing effort is known to occur within the vicinity of the Crux project area. Temporary displacement within the Crux project area. Permanent displacement with the gazetted petroleum exclusion zone will be managed through consultation with fishing representatives and designation on Australian Hydrographic Office nautical charts. |
| | Shipping | Temporary displacement of commercial shipping within the Crux project area (excluding petroleum safety zones) is acceptable.<br>Permanent exclusion of commercial shipping from gazetted petroleum exclusion zones is acceptable. | Yes, project impacts and risks are of an acceptable level, given commercial shipping in the project area is negligible. The nearest major shipping channel is approximately 560 km to the west of the proposed Crux platform. Temporary displacement within the Crux project area, and permanent displacement with the gazetted petroleum exclusion zone, will be managed through consultation with commercial shipping representatives and designation on Australian Hydrographic Office nautical charts. |

**Principles of ESD**

The risks and impacts from the physical presence of the Crux project are consistent with the principles of ESD based on the following points:

- The physical presence and vessel movements aspect of the Crux project does not degrade the biological diversity or ecological integrity of the Commonwealth marine area in the Timor Sea. Significant impacts to MNES will not occur.
- The health, diversity and productivity of the marine environment will be maintained for future generations.
- The project does not significantly impinge upon the rights of other parties to access environmental resources (e.g. commercial and traditional fishers).
- The precautionary principle has been applied, and studies undertaken where knowledge gaps were identified. This knowledge has been applied during the evaluation of environmental impacts and risks.

**Relevant Requirements**

Management of the impacts and risks from the physical presence of the Crux project are consistent with relevant legislative requirements, including:

- compliance with international maritime conventions, including:

  - STCW Convention
  - SOLAS Convention, and
  - COLREGS.

- compliance with Australian legislation and requirements, including:
  - *Navigation Act 2012*:
    - Marine Order 21 (Safety of Navigation and Emergency Procedures)
    - Marine Order 30 (Prevention of Collisions), and
    - Marine Order 71 (Masters and Deck Officers).
  - EPBC Regulations:
    - adherence to the requirements of Part 8 (Interacting with cetaceans and whale watching).
- management of impacts and risks are consistent with policies, strategies, guidelines, conservation advice, and recovery plans for threatened species (**Table 8-9**).

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates significant impacts[6] to threatened and migratory species will not credibly result from the planned direct impacts from the physical presence and vessel movements aspects of the Crux project.

An unplanned collision between project vessels and threatened or migratory fauna (particularly cetaceans) is unlikely to occur and may result in injury to or death of individual animals. This unplanned event is not considered to have the potential for significant impacts to threatened or migratory species.

Alignment of the Crux project with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided in **Table 8-9**.

*Commonwealth Marine Environment*

The impacts and risks from the physical presence of the Crux project on the Commonwealth marine environment do not breach any of the significant impact criteria provided in **Table 7-1** (note that the risk of IMS is considered in **Section 8.4.5**).

The impacts and risks from the physical presence and vessel movements aspect of the Crux project on the continental slope demersal fish communities do not significantly affect the environmental values of the KEF. The overlap between the Crux pipeline corridor and the KEF constitutes a small portion of the total KEF area. The impacts and risks that may credibly arise from the physical presence of the Crux project will not impact upon the environmental values of the KEF. Hence, Shell considers the impacts and risks to the KEF to be acceptable.

[6] As described in Matters of National Environmental Significance – Significant impact guidelines (DoE 2013a).

Table 8-9: Summary of Alignment of the Impacts and Risks from Physical Presence and Vessel Movements Aspect of the Crux Project with Relevant Requirements for EPBC Threatened Fauna

| **Matters of National Environmental Significance** | **MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices)** | **Threats Relevant to the Project** | **Demonstration of Alignment as Relevant to the Project** |
|---|---|---|---|
| Threatened and Migratory species - marine mammals | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Vessel collisions with marine fauna | The impact assessment indicates that vessel collisions with threatened or migratory marine mammals are very unlikely, and the consequence of any such collision would be restricted to an individual animal (refer to **Section 8.4.1.2**). As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | National Strategy for Reducing Vessel Strikes on Cetaceans and other Marine Megafauna (Commonwealth of Australia 2017c) | Vessel collisions with marine fauna | The Crux project is aligned to 'Objective 3: Mitigation' of Strategy by:<br>• maintaining separation of vessels and whales<br>• maintaining slow vessel speeds, and<br>• avoidance manoeuvres.<br>This will be met by project vessels adhering to Part 8 (Interacting with cetaceans and whale watching) of the EPBC Regulations.<br>Note the other objectives of the Strategy relate to actions for Government agencies. |
| | Conservation advice on sei whale (*Balaenoptera borealis*) (DoE 2015c) | Vessel collisions with marine fauna | The risk of vessel strikes will be managed by project vessels adhering to Part 8 (Interacting with cetaceans and whale watching) of the EPBC Regulations. |
| | Conservation advice on fin whale (*Balaenoptera physalus*) (DoE 2015d) | Vessel collisions with marine fauna | |
| | Conservation management plan for the blue whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015-2025 (Commonwealth of Australia 2015a) | Vessel collisions with marine fauna | |
| | Conservation advice on humpback whale (*Megaptera novaeangliae*) (DoE 2015b) | Vessel collisions with marine fauna | |
| Threatened and Migratory species - marine reptiles | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Vessel collisions with marine fauna | The impact assessment indicates that vessel collisions with threatened or migratory marine reptiles are very unlikely, and the consequence of any such collision would be restricted to an individual animal (refer to **Section 8.4.1.2**). As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |

| Matters of National Environmental Significance | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| | Recovery Plan for Marine Turtles in Australia 2017-2027 (Commonwealth of Australia 2017b) | Vessel collisions with marine fauna | Project vessel interactions with turtles are inherently unlikely due to the offshore location (and resultant low densities of turtles), slow speeds of project vessels and diving startle response of turtles. |
| | Conservation advice on leatherback turtle (*Dermochelys coriacea*) (DEWHA 2009a) | Vessel collisions with marine fauna | |
| Threatened and Migratory species - sharks and rays | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Vessel collisions with marine fauna | The impact assessment indicates that vessel collisions with threatened or migratory sharks and rays are very unlikely, particularly given these taxa spend relatively little time at the sea surface. The consequence of any such collision would be restricted to an individual animal (refer to **Section 8.4.1.2**). As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | Conservation advice on whale shark (*Rhincodon typus*) (DoE 2015l) | Habitat disruption from mineral exploration, production and transportation | The project area is not recognised as habitat critical to the survival of whale sharks, although the project overlaps a broad BIA that represents a migration corridor. The conservation advice recommends minimising offshore developments close to marine features that may aggregate whale sharks and cites Ningaloo Reef and Christmas Island as examples. Studies of whale sharks tagged while aggregating at Ningaloo Reef have shown individuals transiting through the Timor Sea (Meekan and Radford 2010) but showed no evidence of aggregation around particular marine features in the open offshore waters within or in the vicinity of the project area. |
| Commonwealth marine area | Significant Impact Guidelines for the Commonwealth marine environment (**Table 7-1**) | Physical disturbance of the seabed.<br>Vessel collisions with marine fauna. | The impact assessment indicates that the physical presence and vessel movements aspect of the Crux project will not exceed the Commonwealth marine environment significant impact criteria provided in **Table 7-1**. |

#### Internal and External Context

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

#### Acceptability Summary

The assessment of impacts and risks from the physical presence determined the residual impact and risk rankings were all minor or lower (**Table 8-7**). As outlined above, the acceptability of the impacts and risks from the physical presence of the Crux project has been considered in the context of:

- the established acceptability criteria for the physical presence and vessel movements aspect of the Crux project
- ESD
- relevant legislative requirements
- external context (i.e. likely stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are minor. Shell considers residual impacts of minor or lower to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to physical presence and vessel movement aspects of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from the physical presence of the Crux project to be acceptable.

### 8.4.1.5 Environmental Performance Outcomes

#### Physical and Biological Environment

Direct impacts to benthic habitats from the Crux project will be limited to < 0.1% of the total project area.

Direct seabed disturbance from the Crux project will be limited to < 315,980 m$^2$.

Impacts to the continental slope demersal fish communities KEF will be limited to <1% of the total area of the KEF.

No direct loss of coral communities (coral colony) at Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal will occur as a result of the Crux project.

#### Threatened Species and Ecological Communities

No collisions between project vessels and marine fauna resulting in mortality or injury of species listed as threatened or migratory under the EPBC Act will occur within the Crux project area.

**Socio-economic Environment**

No adverse interactions[7] between Shell's activities within the Crux project area and other marine users.

Displacement of other marine users within the Crux project area restricted to:

- temporary displacement from project activities (e.g. from pipelaying vessels and drilling activities), and
- exclusion from gazetted Petroleum Safety Zones (e.g. 500 m exclusion around the Crux platform).

Other marine users will be provided with information on the timing, nature and scale of aspects of the Crux project through Shell's consultation program.

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

### 8.4.2 Light Emissions

#### 8.4.2.1 Project Context

Artificial light emissions will be generated from two primary sources:

- navigational and operational lighting required for functional operation, and
- flaring activities.

Refer to **Section 5.7.3** for additional information on these sources. Functional lighting is required on vessels, drill rigs, and the offshore Crux platform at levels that provide a safe working environment for personnel for safety and navigational purposes, typical of offshore vessels and facilities. Light emissions are also associated with intermittent flaring and will vary in duration and intensity.

Given the current concept for the Crux project is a NNM platform containing minimal processing facilities, utility systems and accommodation, to be operated remotely from the Prelude FLNG facility and only require periodic maintenance visits, this significantly reduces light exposure to the surrounding marine environment.

#### 8.4.2.2 Overview of Light Modelling

A modelling study was commissioned by Shell to inform the assessment of impacts and risks from light arising from the Crux project (Imbricata 2018). The objective of the light study was to characterise the primary sources of light emissions from the Crux project and assess the predicted impact of light in the context of the nearest sensitive receptors.

The report documenting the assessment is provided in **Appendix H**, with a summary of the approach provided below.

The study was undertaken in two primary stages:

- line of sight (LOS) modelling – LOS modelling was undertaken to determine the extent of direct light to the horizon from the Crux project light sources and identify which receptors fall within this area, and
- light intensity modelling – light intensity modelling was undertaken to calculate the intensity of luminance from the light sources to ambient light conditions.

In the context of the in-field development area, the nearest receptors are the submergent shoals (Goeree, Eugene McDermott and Vulcan Shoals), and the nearest emergent coastline (Cartier Island, representing the nearest turtle nesting beach) is approximately 105 km from the Crux platform.

This section evaluates the environmental impacts and risks associated with the light emissions aspects of the Crux project. Key light sources subject of evaluation include the Crux platform, a drill rig, and a supply vessel. At the current stage of early engineering definition, the lighting design has not commenced and not likely to be definitively completed until significantly later in detailed design. Therefore, for this early stage assessment, the assumed inputs draw on comparable analogue data to present a current conservative project estimation of what could be reasonably expected in typical light scenarios from the Crux project.

#### 8.4.2.3 Description and Evaluation of Impacts and Risks

The presence of artificial lighting associated with activities during all phases of the Crux project has the potential to impact marine fauna and birds, particularly those that use visual cues for orientation, navigation, or other purposes. Impacts from artificial lighting associated with the Crux project may include:

- disorientation, attraction or repulsion
- disruption to natural behavioural patterns and cycles, and
- secondary impacts such as increased predation and reduced fitness.

To inform the evaluation of potential impacts and risks, the potential area of influence from light, as informed by the LOS modelling and light intensity modelling is required to place the potential effect on receptors into context.

The results of the LOS modelling are shown in **Figure 8-3**. The LOS modelling shows that light from the Crux project is not expected to reach any of the emergent receptors (e.g. Cartier Island, Ashmore Reef, or Browse Island) under any scenario.

The assessment shows that the theoretical limit of visibility from the Crux platform may extend up to 38.3 km during a safety flaring event, 34.1 km during maintenance flaring, 33.7 km during operation and 22.6 km during start-up activities. The direct light from all flaring scenarios has potential to be visible at Goeree Shoal, Eugene McDermott Shoals and Vulcan Shoal (**Figure 8-3**; Imbricata 2018), however these represent submergent receptors with limited influence from atmospheric light.

Lights of the Crux platform and the drill rig and mast (assumed to be 25 m above sea level) may be visible at distances of 30.9 km, encompassing Goeree Shoal and Eugene McDermott Shoals. The Crux platform and drill rig decks (assumed to be 25 m above sea level) may be visible on the horizon at a distance of 17.9 km, which would be seen from Goeree Shoal. The lights of a supply vessel in the in-field development area may be visible on the horizon at a distance of 19.6 km (Imbricata 2018; **Appendix H**).

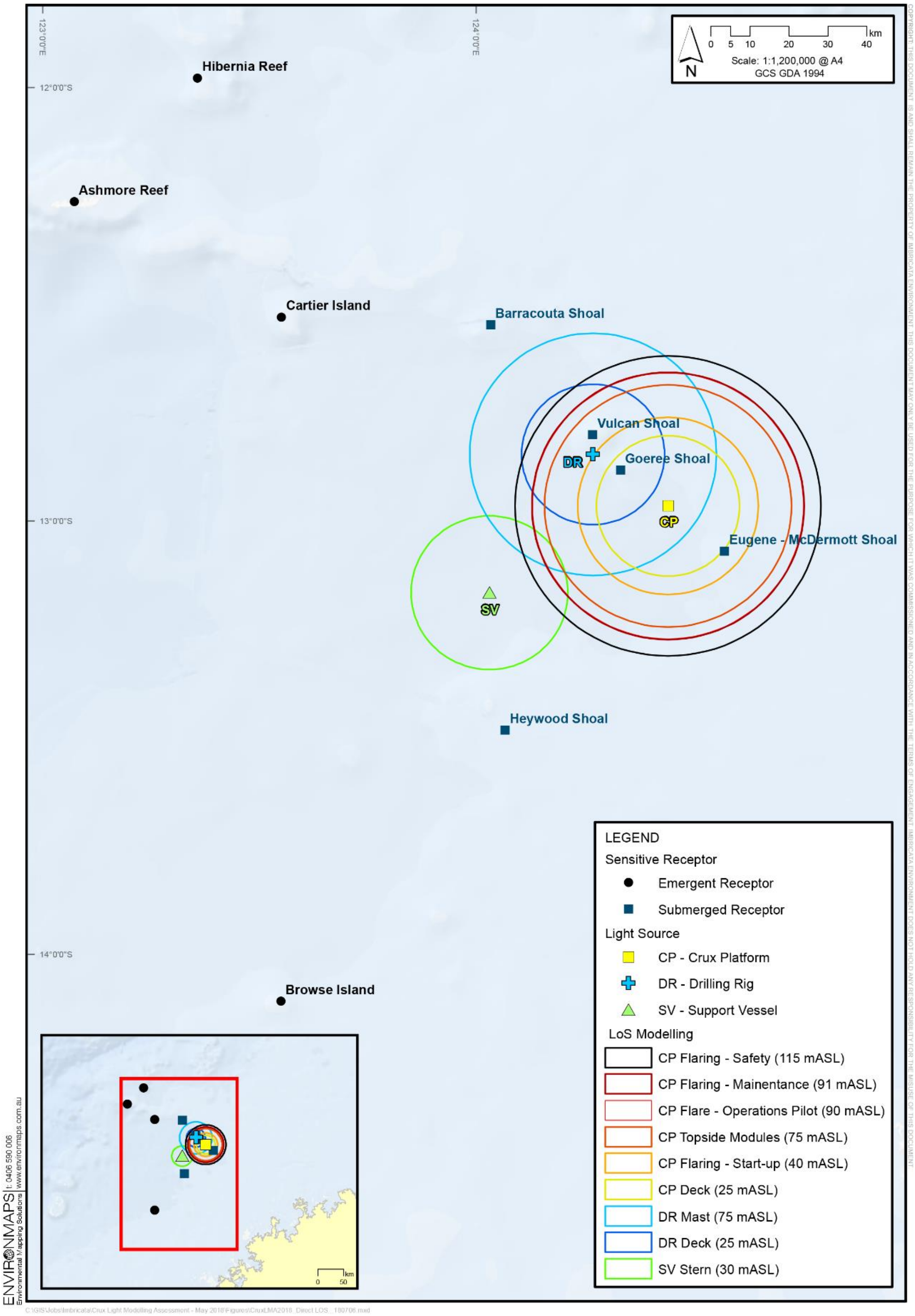



Figure 8-3: Line-of-sight Assessment of Limit of Visibility from the Crux Project

Building on the results of the LOS analysis, light intensity modelling was subsequently undertaken to provide an indication of the outputs for:

- periodic flaring scenarios from the Crux platform – safety flaring, start-up flaring, and maintenance flaring events, and
- operational scenarios – reflecting unmanned and manned operational situations respectively.

The results of the light intensity modelling are summarised in **Table 8-10** (Imbricata 2018).

To contextualise these results, light intensity represents the intensity of light that arrives at or leaves a surface, as perceived by the human eye, and is typically measured in Lux. The total amount of light as it arrives at a surface is referred to as illuminance and is the parameter that has been modelled in this assessment. Light intensity decreases as distance increases from the source of light.

Comparison of the results can be made with typical ambient light conditions, as summarised below:

- > 1 Lux (day light)
- 0.1–1.0 Lux (full moon to twilight)
- 0.01–0.1 Lux (quarter moon to full moon), and
- 0.001–0.01 Lux (moonless clear night to quarter moon).

Table 8-10: Extent of Horizontal and Vertical Light Propagation at Ambient Light Conditions (Luminance = 0.001 Lux) for Various Scenarios

| Location of Light Source | Modelling Analogues (max. luminance at 100 m) (Lux) | Horizontal Light Propagation (km) | Key Habitats Reached |
|---|---|---|---|
| *Periodic Flaring Scenarios* | | | |
| Crux platform flare – start up | 1.1 | 3.2 | None |
| Crux platform flare – safety event | 103 | 32 | Goeree Shoal, Eugene McDermott Shoals, Vulcan Shoal |
| Crux platform flare – maintenance | 0.5 | 2.2 | None |
| *Continuous Operations* | | | |
| Crux platform flare – pilot (unmanned) | 0.5 | 2.2 | None |
| Crux platform deck and topside modules (manned) | 8.9 | 9 | None |
| Drilling rig deck and mast | 8.9 | 9 | Goeree Shoal, Vulcan Shoal |
| Support vessel stern | 8.9 | 9 | None |

The model outputs of the horizontal propagation of light for these scenarios are presented in luminance/distance graphs to show the exponential attenuation of light with distance (as summarised in **Figure 8-4**; Imbricata 2018).

These plots show that the extent of light propagation at ambient conditions from a flaring event at the Crux platform was 32 km, which would reach Goeree Shoal (Ev = 0.0061 Lux), Eugene McDermott Shoals (Ev = 0.0031 Lux) and Vulcan Shoal (Ev = 0.0021 Lux), all of which represent low light levels comparable to a moonless clear night. The extent of light propagation was significantly less for the start-up flaring scenario (3.2 km) and maintenance flaring (2.2 km) from the Crux platform (Imbricata 2018). Taking into account the results of the light modelling, none of the sensitive receptors would be affected by light intensity greater than 0.001 Lux (i.e. comparable to a moonless clear night).

The results of light intensity modelling for the operational scenarios similarly show low levels of light influence. The extent of continuous pilot flaring (assuming a period when the platform is unmanned, consistent with the NNM operational philosophy) is predicted to be 2.2 km. The functional lighting to ambient conditions is predicted to be 9 km from the Crux platform (when manned), drill rig and supply vessel (Imbricata 2018). Therefore, light from a drill rig may reach the nearest submergent receptors of Goeree Shoal (Ev = 0.0055 Lux) and Eugene McDermott Shoals (Ev = 0.0014 Lux), while the other light sources would not reach any of the key habitats at intensities greater than 0.001 Lux.

**Ecosystems, Communities and Habitats**

*Shoals and Banks*

Given the low levels of light reaching the shoal habitats nearest to the Crux project (comparable to a moonless clear night, as shown by the light assessment presented in the preceding section) and that they are submergent features, with no emergent features such as nesting beach or tidal flats, the flaring and functional lighting scenarios pose a low risk to sensitive receptors within the outer area of influence. The shoals surrounding the in-field development area are not known to support large areas of coral communities, with the closest large reef system at Cartier Island (105 km from the Crux platform). Therefore, it is unlikely that the project lighting will impede or disturb natural lighting cycles that may affect coral spawning.

*Offshore Reefs and Islands*

As summarised previously, light from the Crux project is not expected to reach any of the emergent receptors (e.g. Cartier Island, Ashmore Reef, or Browse Island) under any scenario. Therefore, it is concluded that there are no significant impacts from light emissions anticipated to be experienced at these distances.

**Threatened Species and Ecological Communities**

*Marine Reptiles*

The project area does not contain any emergent land or shallow features that may be of importance to nesting or foraging turtles, as the primary marine reptile group that may be influenced by light emissions. Therefore, turtles are unlikely to be present in the area in significant numbers. However, it is reasonably assumed that turtles may transit the project area as they move from nesting beaches and offshore areas.

Light pollution on nesting beaches can alter nocturnal behaviours in adult and hatchling turtles. Artificial lighting can disrupt or affect the choice of nesting location by female turtles, particularly light visible on the landward side of nesting beaches (Salmon et al. 1992). Turtle hatchlings leaving nesting beaches are particularly sensitive to artificial lighting as they use celestial cues to orientate (Limpus 2008; Salmon et al. 1992, cited in Lorne et al. 1997). Once in the water, marine turtle hatchlings may still use celestial lights as navigational markers during oceanic migrations and are known to be attracted towards bright lights. Hatchlings can become disorientated and trapped within light spill around platforms and vessels, resulting in increased energy expenditure, increased predation and decreased survival rates.

Extensive light attraction studies have been conducted on turtle hatchlings, including at Barrow Island (Pendoley 2005). These studies demonstrated that hatchlings crawl away from tall, dark horizons (sand dunes and vegetation) towards lower and lighter horizons (the sea and stars), and that artificial lighting can alter this response. Studies have demonstrated that when on land, hatchlings are not significantly affected by artificial light at a distance of 800 m (Pendoley 2005). Once in the water, hatchling navigation is understood to be influenced predominantly by wave motion, currents and the earth's magnetic field.

The results of the Crux light assessment show that light from the Crux platform is not expected to reach any of the emergent receptors which represent nearest turtle nesting beaches (nearest being Cartier Island, approximately 105 km from the Crux platform). Therefore, there is no potential for adverse disturbance to hatchling turtles arising from the project. Adult turtles passing through the offshore in-field development area may temporarily alter their normal behaviour whilst attracted to the light spill from infrastructure. Given the wide migratory distribution (i.e. several hundred kilometres) of adult turtles outside of nesting season and their low density presence within the offshore in-field development area, the area of influence and subsequent attraction from direct lighting is expected to be minor and a temporary disruption to a small portion of the adult turtle population.

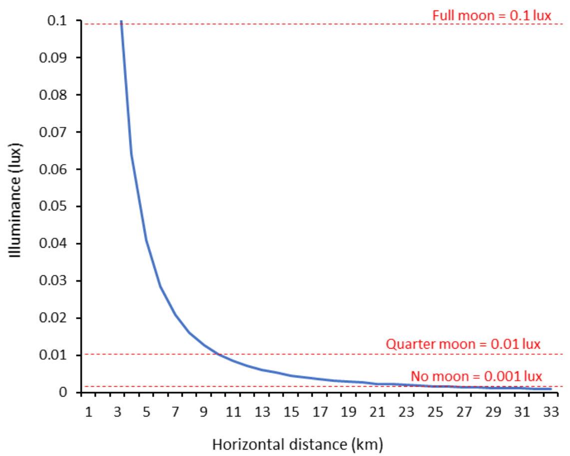
*Birds*

Studies conducted in the North Sea confirmed that artificial light was the reason that seabirds were attracted to and accumulated around lit offshore infrastructure (Marquenie et al. 2008) and that lights can attract birds from large catchment areas (Wiese et al. 2001). Either seabirds may be attracted by the light source itself or indirectly as structures in deep water environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds (Surman 2002, cited in Apache Energy 2008). The light from operating production facilities may also provide enhanced capability for seabirds to forage at night. Negative potential impacts to seabirds attracted by artificial lighting are limited but include collisions with infrastructure and alteration of normal behaviours.

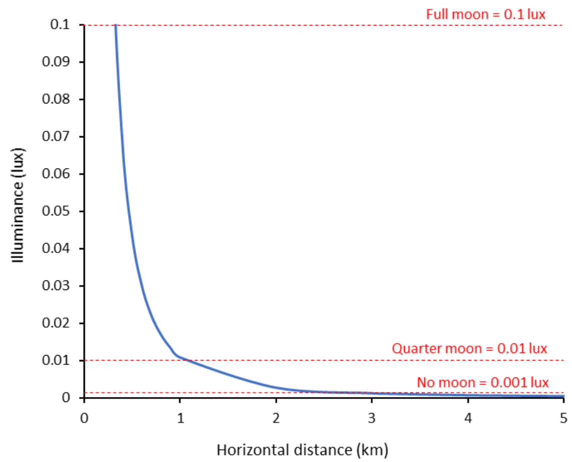
Migratory birds are thought to use the Earth's magnetic field as a reference when undertaking migrations (Archer 2017; Chernetsov 2016; Chernetsov et al. 2017; Heyers et al. 2017), although may rely on other cues such as visual cues for shorter-range movements. Light from offshore platforms in the North Sea have been shown to attract migrating birds and birds that migrate during the night are especially affected (Verheijen 1985). Light from the Crux project may potentially attract migratory birds, however given the Earth's magnetic field is the primary navigation cue, the Crux project is not expected to have any influence on large-scale bird migrations.

It is reasonably expected that light will project vertically from the Crux project activities, although the actual vertical propagation is highly influenced by the degree of variability in atmospheric conditions (e.g. cloud density, cover and ceiling height, aerosols and suspended participles). The natural behaviour of migratory birds may be affected when entering the area of influence as they will see the light source from a flying altitude. Given that only a small number of individuals are expected to pass within the area of influence whilst in transit, any behavioural disturbances such as disorientation, attraction and/or exhaustion are considered to potentially affect a small proportion of individual birds, and not expected to result in any population level effects on even a local scale.

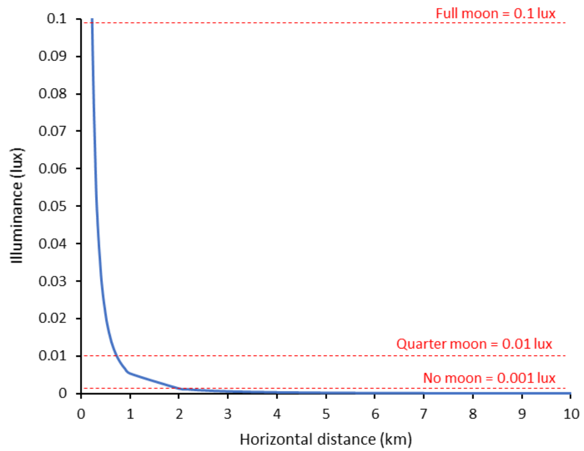
Given the location of the Crux project in a remote offshore location, distant from known migratory aggregation areas for birds, and with the low lighting requirements for a NNM operational platform philosophy, significant impacts arising from light emissions are not expected.



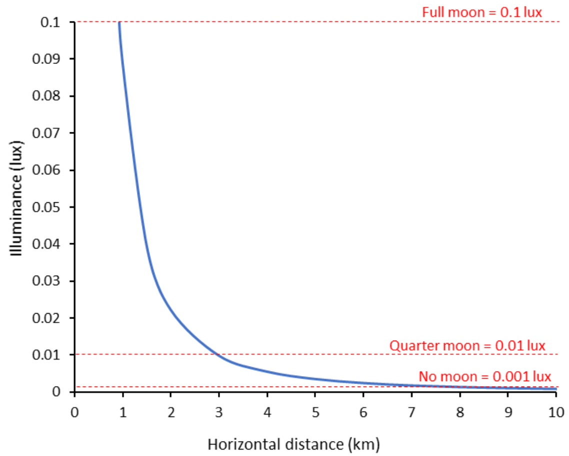

a) Predicted light propagation during a safety flaring event from the Crux platform




b) Predicted light propagation during a start-up flaring scenario from the Crux platform




c) Predicted light propagation during pilot (unmanned) scenario from the Crux platform




d) Predicted light propagation from the Crux platform (manned), drill rig and supply vessel

Figure 8-4: Light Intensity Modelling Outputs for Different Scenarios

#### 8.4.2.4 Risk and Impact Summary and Key Management Controls

Table 8-11: Light Emissions Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Planned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Magnitude | Sensitivity | Residual Impact |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from light emissions arising from the Crux project | | X | X | | Minor effect | Medium | Minor |
| ***Key Management Controls*** | | | | | | | |
| External lighting on offshore facilities/infrastructure will be minimised through design to that required for navigation, safety of deck operations and security considerations, except in the case of an emergency.<br>Flaring during operations is optimised to enable the safe and economically efficient operation of the facility. | | | | | | | |

#### 8.4.2.5 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the light emissions aspect of the Crux project are summarised in **Table 8-12**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the light emissions aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the light emissions aspect of the Crux project is provided below.

Table 8-12: Acceptable Levels of Impacts and Risks from Light Emissions

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Ecosystems, Communities and Habitats | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of coral communities at named banks or shoals as a result of indirect/offsite[8] impacts associated with the Crux project. | Yes. Given the distance to the nearest shoal (approximately 13 km to Goeree Shoal), fauna at the shoals and banks are unlikely to perceive light from the Crux platform. Hence, they are unlikely to be impacted.<br>Future tieback wells may be drilled closer to the shoals within the Crux in-field development area (although no activities will occur within the 1 km buffer surrounding the shoals). Given the depths of the shoals and the buffer applied, lighting from drilling activities |

[8] As defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoEE 2013).

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| | | | perceived by fauna at the shoals is expected to be similar to a moonlit night. This is not considered to be a direct impact. |
| Threatened Species and Ecological Communities | Key fauna species | No mortality or injury of threatened MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory fauna. | Yes. Light from vessels may result in temporary attraction of threatened and migratory birds. This attraction will be of short duration and will not result in significant impacts or mortality. Lighting on the Crux platform may also attract threatened and migratory birds, which may roost on the platform. This will not result in significant impacts or mortality. |

**Principles of ESD**

The risks and impacts from light emissions from the Crux project are consistent with the principles of ESD based on the following points:

- the light emissions aspect of the Crux project does not degrade the biological diversity or ecological integrity of the Commonwealth marine area in the Timor Sea. Significant impacts to MNES will not occur.
- the precautionary principle has been applied, and studies undertaken where knowledge gaps were identified. This knowledge has been applied during the evaluation of environmental impacts and risks.

**Relevant Requirements**

Management of the impacts and risks from light emissions associated with the Crux project are consistent with relevant legislative requirements, including:

- management of impacts and risks are consistent with policies, strategies, guidelines, conservation advice, and recovery plans for threatened species
- implementation of recognised industry standard practice, such as:
  - external lighting on offshore facilities/infrastructure will be minimised to that required for navigation, safety of deck operations and security considerations, except in the case of an emergency.

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates significant impacts[9] to threatened and migratory species will not credibly result from the light emissions aspect of the Crux project.

Alignment of the Crux project with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided in **Table 8-13**.

[9] As described in Matters of National Environmental Significance - Significant impact guidelines (DoE 2013)

*Commonwealth Marine Environment*

The impacts and risks from the light emissions aspect of the Crux project on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Table 7-1**.

Table 8-13: Summary of Alignment of the Impacts and Risks from Light Emissions Aspect of the Crux Project with Relevant Requirements for EPBC Threatened Fauna

| Matters of National Environmental Significance | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| Threatened and Migratory species - birds | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Artificial light emissions | The evaluation of environmental impacts and risks indicates that impacts from artificial light emissions on threatened or migratory marine mammals are very unlikely and would not constitute a significant impact. As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | Wildlife Conservation Plan for Migratory Shorebirds (DoE 2015) | Artificial light emissions | The Crux project is aligned to 'Objective 4' of the plan by ensuring that anthropogenic disturbance is considered in development assessment processes. Migratory birds have been considered as an environmental receptor in the evaluation of impacts and risks. |
| Threatened and Migratory species - marine reptiles | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Artificial light emissions | The evaluation of environmental impacts and risks indicates that impacts from artificial light emissions on threatened or migratory marine reptiles are very unlikely and would not constitute a significant impact. As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | Recovery Plan for Marine Turtles (DoEE 2017) | Artificial light emissions | Light pollution has been identified as a threat in the Recovery Plan for Marine Turtles (DoEE 2017). Nesting females and hatchling turtles are at greatest risk of light impacts; however, the nearest potential nesting habitat is Cartier Island (approximately 105 km from the Crux platform). Potential light-related impacts to turtles on nesting beaches is not considered credible.<br>Actions in the Recovery Plan for Marine Turtles (DoEE 2017) relating to the threat of artificial light include:<br>• 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<br>• develop and implement best practice light management guidelines for existing and future developments adjacent to marine turtle nesting beaches, and<br>• identify the cumulative impacts on turtles from multiple sources of onshore and offshore light pollution<br>Given the Crux project area is beyond any BIAs or habitat critical for the survival of marine turtles (e.g. nesting, inter-nesting or foraging areas) and the light modelling studies (Imbricata 2018) indicate that potential impacts to marine turtles will not extend beyond the Crux project area, the actions listed above are not applicable to the Crux project. |
| Commonwealth marine area | Significant Impact Guidelines for the Commonwealth marine environment (**Table 7-1**) | Artificial light emissions | The evaluation of environmental impacts and risks indicates that the light emissions aspect of the Crux project will not exceed the Commonwealth marine environment significant impact criteria provided in **Table 7-1**. |

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from light emissions determined the residual impact and risk ratings were Minor or lower (**Table 8-11**). As outlined above, the acceptability of the impacts and risks from light emissions associated with the Crux project has been considered in the context of:

- the established acceptability criteria for the light emissions aspect of the Crux project,
- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are minor. Shell considers residual impacts of minor or lower to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to the light emission aspect of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from light emissions associated with the Crux project to be acceptable.

### 8.4.2.6 Environmental Performance Outcomes

**Biological Environment**

No mortality or injury of threatened and migratory MNES species as a result of artificial light emissions from the Crux project.

### 8.4.3 Underwater Noise

#### 8.4.3.1 Project Context

Aspects of the Crux project will generate underwater noise above ambient levels. This noise may result in impacts and risks to environmental receptors. These aspects are described in **Section 5.7.4** and include:

- pile driving activities for the installation of the platform foundations
- development drilling
- vertical seismic profiling (VSP) during drilling activities, and
- vessels-related noise, particularly while using dynamic positioning (DP).

An underwater water noise assessment, including numerical sound transmission loss modelling, was undertaken for each of these noise sources. A description of the assessment and key results is provided in **Section 8.4.3.2**; the modelling report is provided as **Appendix I**.

Underwater noise may be generated by other sources associated with the Crux project, such as the operation of subsea infrastructure (e.g. noise generation from fluid flow through choke valves, discharge of PFW to the sea surface, subsea compression etc.). Many of these low intensity noise sources will be continuous during the operational phase of the development. Monitoring of operational offshore oil and gas facilities indicates these sources have little potential for environmental impacts (Erbe et al. 2013, McCauley 2002).

The propagation of noise in the marine environment is influenced by many factors, such as:

- the characteristics of the noise (e.g. frequency, intensity, location)
- the characteristics of the water column (e.g. density interfaces, water depth, sea surface state), and
- the characteristics of the sediment (e.g. capacity to reflect and absorb noise).

The aspects that may generate noise, and the characteristics of the noise, are discussed further below. The characteristics of the water column (e.g. density) and seabed will affect the transmission of underwater noise in the marine environment. As the majority of underwater noise associated with the Crux project will be generated within the in-field development area, the water column and seabed characteristics at this location have been used for the basis of the impact assessment (including the modelling studies described in **Section 8.4.3.2** and presented in **Appendix I**).

**Underwater Noise Units Explained**

Underwater (and atmospheric) noise is typically measured in units of decibels (dB), which are base 10 logarithmic units of sound pressure. Human perception of the intensity of sound is approximately logarithmic, making decibels a commonly used unit. Decibel measurements require use of a reference pressure; all underwater noise measurements presented in this OPP use a reference pressure of 1 micropascal (1 µPa). This reference pressure is commonly used in studies assessing the potential environmental impacts of underwater noise, which facilitates comparisons between measurements.

Underwater noise frequency is a measure of the pitch of noise. It is measured in units of hertz (Hz), which is a measure of the number of sound wave amplitude peaks (i.e. cycles) per second. Underwater noises may cover a relatively narrow frequency band or a broad frequency band. For example, noise from seismic energy sources is highly concentrated in relatively low frequencies and is hence relatively narrow band. In contrast, noise energy from vessel thruster cavitation is spread over a large range of frequencies and hence is relatively broadband in nature.

Underwater noise can generally be considered as two types:

- impulsive noise – typically discrete, short duration noises punctuated by periods of low/no noise, characterised by high peak sound pressure levels with relatively rapid rise and decay times, and
- non-impulsive – noises that do not have rapid rise and decay times, typically of longer duration.

The difference in the nature of these noise types may result in different mechanisms for environmental impacts. Two different underwater noise units have been applied to quantifying each type. Impulsive noises, such as piling and VSP, have been quantified as Sound Exposure Level (SEL, or $L_{E,p}$) using units of dB re 1 µPa$^2$.s. Non-impulsive noises have been quantified as Sound Pressure Level (SPL, or $L_p$) using units of dB re 1 µPa. The maximum peak pressure level ($L_{pk}$) is the absolute peak pressure (i.e. peak amplitude) of a sound pressure wave (either impulsive or continuous) in dB re 1 µPa.

Refer to the *Principles of Underwater Noise* attached to **Appendix I** for additional information.

**Piling**

The installation of Crux platform jacket legs may require piling. While the piling method has yet to be finalised, it is expected that installation will require the use of a hydraulic hammer to drive the piles into the seabed. Piling activity will only occur at the Crux platform location. The number of piles required is yet to be finalised, however an indicative number of 12–16 piles are expected to be installed. Hammering of individual piles is expected to require less than 24 hours of continuous hammering. Hammering of consecutive piles will not occur continuously; there will be a break between the hammering stage for the installation of each pile.

Piling noise is not continuous, with each strike of the hammer on the pile generating a short, discrete sound impulse. This type of noise contrasts with continuous sources of noise, such as continuous use of vessel thrusters. Piling will not be undertaken concurrently with drilling or VSP.

Piling has the potential to generate high-intensity noise when the hammer strikes the pile. Each hammer strike induces the pile to vibrate briefly, converting some of the energy applied to the pile into a pressure wave in the water column. This pressure wave is perceived as noise and is radiated from the pile into the water column. The vibration of the pile may also result in a pressure wave propagating along the density interface between the sediment and water column. An indicative SEL for piling using a relatively large (2,027 kilojoules (kJ)) hammer is approximately 220 dB re 1 µPa$^2$.s. The frequency spectrum of piling is expected to be broad, with most energy concentrated between 10 hertz (Hz) and 2,000 Hz.

**Drilling**

Drilling of the foundation wells, and any tieback wells, will be carried out using a semi-submersible rig. The semi-submersible rigs suitable for use in the in-field development area are typically moored, although other methods to hold station may be used (e.g. dynamically positioned). Drilling activities will result in the generation of underwater noise, with most noise being generated through vibration of the drill string and the transmission of machinery noise through the rig hull (SVT Engineering Consultants 2018). Foundation drilling will occur at the proposed Crux platform location. The drilling locations for future tieback wells are not yet determined, although these locations will be within the in-field development area. A typical offshore well of the depths required for the Crux project is expected to take 60–120 days to drill, excluding any operational or weather-related delays and associated well completion activities which does not involve actual drilling.

The noise generated by drilling operations, excluding the use of thrusters for DP (refer to **Vessels** below for information on thruster noise) is relatively low intensity continuous noise. Extrapolation from measurements of underwater noise from a semi-submersible drilling rig by McCauley (1998) indicates noise source levels for non-drilling and drilling noise from a rig range from 160 to 164 dB re 1 µPa at 1 m (SVT Engineering Consultants 2018).

**Vertical Seismic Profiling**

VSP is a standard well logging technique that is routinely used to collect geophysical measurements within well bores. VSP is not expected to be used in relation to the foundation wells but may be used on future tieback wells. VSP typically involves the use of a seismic energy source (e.g. a single air gun or a small air gun array) suspended in the water column and a receiver (e.g. hydrophone or geophone) suspended within the well bore. The seismic source may be suspended directly below the drilling rig or may be offset (e.g. suspended behind a vessel). Vertical seismic profiling typically required noise emissions between 8 hours and 24 hours per well. VSP will not be undertaken concurrently with piling.

VSP noise is not continuous. Each discharge of the seismic source generates a short, discrete, low frequency sound impulse. Seismic impulses during VSP are typically much lower than those generated during typical marine seismic surveys. Source levels for typical VSP seismic energy sources is estimated at 193.5 dB re 1 µPa$^2$.s, with the majority of the noise energy occurring at low frequencies (< 100 Hz) (SVT Engineering Consultants 2018).

**Vessels**

Vessels will be required during all phases of the Crux project, with relatively high levels of use during installation and hook-up of facilities and decommissioning. The types of vessels used will range from relatively small supply vessels to large pipelay and heavy lift vessels (**Table 5-5**). Vessel activity will be concentrated around the proposed Crux platform location and within the export pipeline corridor but will occur throughout the in-field development area.

Vessels may generate underwater noise from propellers and thrusters, which tend to generate considerable noise due to cavitation. Thruster nose is typically the highest intensity noise source generated by the vessels that may be used during the Crux project. Other noise sources include the transmission of machinery noise (e.g. main engines) through the hull and signal noise from acoustic survey equipment (e.g. multibeam echo sounders).

Vessels will often be required to hold station throughout the project area. This is a critical safety requirement that cannot be avoided. Vessels holding station typically do so using DP, during which the vessel's navigation system will automatically control the vessel's thrusters to hold a given position. Holding position by DP typically requires considerable use of thrusters; hence vessels using DP may generate considerable underwater noise.

Thruster noise is typically broad-band in nature, with a noise frequency spectrum ranging from < 10 Hz to > 8,000 Hz (McCauley 1998; SVT Engineering Consultants 2018).

Extrapolation from measurements of underwater noise from a support vessel holding station by McCauley (1998) indicates the noise source level for a support vessel holding station using DP up to 183 dB re 1 µPa at 1 m (SVT Engineering Consultants 2018).

### 8.4.3.2 Overview of Underwater Noise Modelling

Numerical modelling of underwater noise propagation was carried out by SVT for the following sources (**Appendix I**):

- piling
- development drilling
- VSP, and
- vessel noise.

The scenarios modelled for each of these noise sources are summarised in **Table 8-14**. The modelling report is provided as **Appendix I**.

Table 8-14: Summary of Modelled Underwater Noise Sources

| Source | Location | Duration | Source Level |
|---|---|---|---|
| *Impulsive Noise* | | | |
| Piling (632 kJ hammer) | Proposed Crux platform location | 16 days (assuming 16 piles installed at a rate of 1 per day) | 214 dB re 1 µPa$^2$.s @ 1 m |
| Piling (2,027 kJ hammer) | Proposed Crux platform location | 16 days (assuming 16 piles installed at a rate of 1 per day) | 220 dB re 1 µPa$^2$.s @ 1 m |
| VSP | Proposed Crux platform location | 10 shots per event, one event per day | 193.5 dB re 1 µPa$^2$.s |
| *Continuous Noise* | | | |
| Drill rig | In proximity to Eugene McDermott Shoal (outside 1 km buffer) | Continuous | 167 dB re 1 µPa @ 1 m |
| | In proximity to Vulcan Shoal (outside 1 km buffer) | Continuous | |
| | Proposed Crux platform location | Continuous | |
| Vessel using DP | Proposed Crux platform location | Continuous | 171 dB re 1 µPa @ 1 m |

The sound speed profile of the water column used for the modelling was derived from in-field water column measurements in the in-field development area. Conditions resulting in the greatest sound propagation were observed during the month of July. These conditions were the “worst-case” and were applied to the modelling studies to provide an inherently conservative assessment. The modelling studies included the nature of the seabed, as measured during geophysical investigations of the in-field development area. Sea surface scattering was not considered in the model. This makes the results of the model more conservative (i.e. the model is likely to over-estimate received noise levels).

#### Underwater Noise Impact Thresholds

Results from the underwater noise modelling studies were compared against a range of impact thresholds for the following key fauna groups:

- marine mammals
- marine turtles
- sea snakes
- fish (including larvae)

- sharks and rays, and
- invertebrates.

Impacts to marine fauna can be grouped as follows in decreasing order of effect:

- mortality or potential mortal injury – physical injury that may result in the death of an animal
- impairment:
  - recoverable injury – physical injury from which an animal is expected to recover,
  - permanent threshold shift (PTS) – a permanent reduction in the ability of an animal to perceive sound. Recovery is not expected to occur.
  - temporary threshold shift (TTS) – a temporary reduction in the ability of an animal to perceive sound. Recovery to a pre-exposure levels is expected to occur, and
  - masking – no change in the ability for an animal to perceive sound, but biologically meaningful sounds may be "drowned out" by anthropogenic noise.
- behavioural impacts – typically short-term behavioural responses such as avoidance, surfacing etc. Behaviour will return to normal following cessation of the anthropogenic noise.

Impact thresholds for fauna groups were derived from scientific literature and published guidelines, including:

- Sound exposure guidelines for fishes and sea turtles: a technical report prepared by American National Standards Institute (ANSI)-Accredited Standards Committee S3/SC1 and registered with ANSI (Popper et al. 2014)
- Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NOAA 2018), and
- Underwater noise piling guidelines (Department of Planning, Transport and Infrastructure 2012).

*Fish, Larvae and Sea Turtles*

The impact thresholds applied during the noise modelling assessment for fish, fish larvae and turtles for impulsive and non-impulsive underwater noise are summarised in **Table 8-15** and **Table 8-16** respectively. These are derived primarily from the extensive review and recommendations of Popper et al. (2014). Refer to **Appendix I** for further discussion on threshold selection.

Table 8-15: Fish, Larvae and Marine Turtle Noise Criteria for Impulsive Noise Sources (Piling and VSP) (SVT Engineering Consultants 2018)

| Type of Animal | Mortality and Potential Mortal Injury | Impairment | | | Behaviour |
|---|---|---|---|---|---|
| | | Recoverable Injury | TTS | Masking | |
| *Piling* | | | | | |
| Fish: No swim bladder (particle motion detection) | > 219 dB $L_{E,p}$<br>or<br>> 213 dB $L_{pk}$ | > 216 dB $L_{E,p}$<br>or<br>> 213 dB $L_{pk}$ | > 186 dB $L_{E,p}$ | (N) Moderate<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Fish: Swim bladder is not involved in hearing (particle motion detection) | 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | 203 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | > 186 dB $L_{E,p}$ | (N) Moderate<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Fish: Swim bladder | 207 dB $L_{E,p}$<br>or | 203 dB $L_{E,p}$<br>or | 186 dB $L_{E,p}$ | (N) High<br>(I) High | (N) High<br>(I) High |

| | | | | | |
|---|---|---|---|---|---|
| involved in hearing (primarily pressure detection) | > 207 dB $L_{pk}$ | > 207 dB $L_{pk}$ | | (F) Moderate | (F) Moderate |
| Eggs and larvae | 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low |
| Marine turtles | > 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | (N) High<br>(I) Low<br>(F) Low | (N) High<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| *VSP* | | | | | |
| Fish: No swim bladder (particle motion detection) | > 219 dB $L_{E,p}$<br>or<br>> 213 dB $L_{pk}$ | > 216 dB $L_{E,p}$<br>or<br>> 213 dB $L_{pk}$ | > 186 dB $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Fish: Swim bladder is not involved in hearing (particle motion detection) | 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | 203 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | > 186 dB $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Fish: Swim bladder involved in hearing (primarily pressure detection) | 207 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | 203 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | 186 dB $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Moderate | (N) High<br>(I) High<br>(F) Moderate |
| Eggs and larvae | 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | (N) High<br>(I) Low<br>(F) Low | (N) High<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Marine turtles | > 210 dB $L_{E,p}$<br>or<br>> 207 dB $L_{pk}$ | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | 175 dB $L_p$<br>164 dB $L_{E,p}$ |
| Note: Where insufficient data existed to recommend objective guidelines, a subjective approach is adopted in which the relative risk (High, Moderate, Low) of an effect is placed in order of rank at three distances from the source – Near (N), Intermediate (I), and Far (F) (top to bottom within each cell of the table, respectively).<br>"Near" might be considered to be in the tens of metres from the source, "intermediate" in the hundreds of metres, and "far" in the thousands of meters. | | | | | |

Notes: $L_{E,p}$ – sound exposure level; $L_p$ – sound pressure level; $L_{pk}$ – peak pressure level

Table 8-16: Fish, Larvae and Marine Turtle Noise Criteria for Continuous Noise Sources (Operations and Vessels) (SVT Engineering Consultants 2018)

| **Type of Animal** | **Mortality and Potential Mortal Injury** | **Impairment** | | | **Behaviour** |
|---|---|---|---|---|---|
| | | **Recoverable Injury** | **TTS** | **Masking** | |
| Fish: No swim bladder (particle motion detection) | (N) Low<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) High<br>(I) High<br>(F) Moderate | (N) Moderate<br>(I) Moderate<br>(F) Low |
| Fish: Swim bladder is not | (N) Low<br>(I) Low | (N) Low<br>(I) Low | (N) Moderate<br>(I) Low | (N) High<br>(I) High | (N) Moderate<br>(I) Moderate |

| | | | | | |
|---|---|---|---|---|---|
| involved in hearing (particle motion detection) | (F) Low | (F) Low | (F) Low | (F) Moderate | (F) Low |
| Fish: Swim bladder involved in hearing (primarily pressure detection) | (N) Low<br>(I) Low<br>(F) Low | 170 dB $L_p$ for 48 hour | 158 dB $L_p$ for 12 hour | (N) High<br>(I) High<br>(F) High | (N) High<br>(I) Moderate<br>(F) Low |
| Eggs and larvae | (N) Low<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) High<br>(I) High<br>(F) Moderate | (N) High<br>(I) Moderate<br>(F) Low |
| Marine turtles | (N) Low<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low | (N) Moderate<br>(I) Moderate<br>(F) Low |
| Note: Where insufficient data existed to recommend objective guidelines, a subjective approach is adopted in which the relative risk (High, Moderate, Low) of an effect is placed in order of rank at three distances from the source – Near (N), Intermediate (I), and Far (F) (top to bottom within each cell of the table, respectively).<br>“Near” might be considered to be in the tens of metres from the source, “intermediate” in the hundreds of metres, and “far” in the thousands of meters. | | | | | |

*Marine Mammals*

The vulnerability of marine mammals to underwater noise is linked to their ability to perceive sound. Cetaceans can be grouped based on similarities in their hearing. Underwater noise exposure thresholds can then be weighted for each cetacean group to emphasise noise frequencies that a group may be particularly vulnerable to. This approach is described in Southall et al. (2007) and has been applied to a range of underwater noise guidelines and impact assessments on cetaceans. The South Australian Government Underwater noise piling guidelines (Department of Planning, Transport and Infrastructure 2012) applied in this assessment use this approach.

The impact thresholds applied during the noise modelling assessment for marine mammals for impulsive and non-impulsive underwater noise are summarised in **Table 8-17**. These are derived primarily from technical guidelines published by NOAA (2018). Refer to **Appendix I** for further discussion on threshold selection.

Table 8-17: Mammal Sound Exposure Criteria

| Type of Animal | PTS – Permanent Injury | | TTS – Impairment | | Behaviour | |
|---|---|---|---|---|---|---|
| | Impulsive | Non-impulsive | Impulsive | Non-Impulsive | Impulsive | Non-impulsive |
| Low-frequency cetaceans | 219 dB $L_{pk}$<br>183 dB $L_{E,p}$ | 199 dB $L_{E,p}$ | 213 dB $L_{pk}$<br>168 dB $L_{E,p}$ | 179 dB $L_{E,p}$ | 160 dB $L_p$ | 120 dB $L_p$ |
| Mid-frequency cetaceans | 230 dB $L_{pk}$<br>185 dB $L_{E,p}$ | 198 dB $L_{E,p}$ | 224 dB $L_{pk}$<br>170 dB $L_{E,p}$ | 178 dB $L_{E,p}$ | 160 dB $L_p$ | 120 dB $L_p$ |
| High-frequency cetaceans | 202 dB $L_{pk}$<br>155 dB $L_{E,p}$ | 173 dB $L_{E,p}$ | 196 dB $L_{pk}$<br>140 dB $L_{E,p}$ | 153 dB $L_{E,p}$ | 160 dB $L_p$ | 120 dB $L_p$ |

Table 8-18: Summary of Cetacean Safety Zones for Impact Piling

| Species | Noise Exposure Threshold SEL in dB(M) re 1 μPa$^2$.s | Observation Zone | Shut Down Zone | Zone of Behavioural Response |
|---|---|---|---|---|
| Low/mid/high-frequency cetaceans | ≤ 150 dB at 100 m | 1 km | 100 m | ≤ 150 m |
| | ≤ 150 dB at 300 m | 1.5 km | 300 m | ≤ 500 m |
| | > 150 dB at 300 m | 2 km | 1 km | ≤ 3 km |

*Other Fauna*

Sharks and rays do not typically have gas-filled cavities such as swim bladders and are considered less vulnerable to underwater noise related injuries. As such, sharks and rays were grouped with fish without a swim bladder (**Table 8-15** and **Table 8-16**) for this assessment of impacts and risks.

No suitable published guidelines were identified for sea snakes. Sea snakes were grouped with fish without a swim bladder (**Table 8-15** and **Table 8-16**) for this assessment of impacts and risks.

While there are reputable published studies indicating the potential for underwater noise to impact upon invertebrates, no suitable published guidelines were identified. Invertebrates have been considered in the assessment of risks and impacts from underwater noise, although no threshold values have been applied.

**Key Modelling Results**

This section summarises the key results and conclusions from the noise assessment study undertaken to inform the assessment of impacts and risks. A detailed presentation of the noise assessment conclusions, including numerical modelling results, is provided in **Appendix I**.

Activities conducted during the Crux project have the potential for localised and temporary impacts on marine fauna, including fish, marine turtles and cetaceans. Based on the thresholds outlined above, underwater noise levels would:

- fall below the relevant permanent injury and fatality criteria where applicable to the marine fauna type, and the relevant instantaneous permanent hearing damage criteria, at all locations.
- fall below the relevant permanent hearing damage criteria based on daily exposures beyond ranges of 389 m for fish and marine turtles, 14 km for mid-frequency cetaceans and 17.3 km for low-frequency cetaceans. The daily exposure criteria are considered extremely conservative, as these require an animal to remain within the exposure zone for 24 hours. This is considered very unlikely as animals, particularly cetaceans, are expected to move away from the noise source as they are inherently highly mobile.
- exceed the relevant temporary hearing threshold shift criteria (pile strike number and exposure time dependent) at ranges of up to 13.3 km for fish and 57.8 km for cetaceans.
- fall below the relevant behavioural disturbance criteria for low-frequency cetaceans at ranges beyond 2.7 km.

### 8.4.3.3 Description and Evaluation of Impacts and Risks

**Ecosystems, Communities and Habitats**

*Benthic Communities*

There is some evidence to suggest components of benthic communities may be vulnerable to underwater noise-related impacts, while other components are not. Studies have indicated scallops exposed to seismic survey noise show increased potential for mortality (Day et al. 2016; Harrington et al. 2010), however no studies have shown evidence of significant or short-term mortality (Przeslawski et al. 2018). The noise intensity from these studies was much higher than the levels that will occur during the Crux project. Preliminary studies on the effects of underwater noise on sponges did not observe any effects attributable to noise exposure (Wilmut et al. 2006).

Underwater noise generated by operational platforms does not appear to have any detrimental effect on benthic communities. Inspection of fixed platforms worldwide shows these structures serve as artificial reefs and develop relatively diverse benthic communities.

Benthic habitat surveys of the project area did not indicate the presence of particularly diverse or sensitive benthic communities. Potentially vulnerable taxa, such as bivalve molluscs, were not observed. Given the duration, frequency spectrum and intensity of potential noise generated during the Crux project, no impacts to benthic communities as a consequence of underwater noise are expected to occur.

*Shoals and Banks*

The shoals and banks near the Crux project may potentially be exposed to increased underwater noise levels as a result of piling, VSP and vessels using DP. These shoals and banks host relatively diverse fauna communities, such as demersal fish and marine turtles (see **Threatened Species and Ecological Communities** below for further discussion). However, given the distance of these shoals and banks from the noise source and the consequential reduction in noise intensity, the received noise levels will be significantly lower than the source levels. The nearest shoal to the Crux platform location is Goeree Shoal, which lies approximately 13 km to the north-west.

The noise assessment (**Appendix I**) indicated that, based on the 24-hour exposure criterion, TTS for fish may occur out to 13.4 km based on the use of the heavy piling hammer. This may result in TTS impacts to fish on a part of Goeree Shoal; received underwater noise levels at Eugene McDermott and Vulcan shoals will not exceed any impact thresholds for fish. Given the short duration of the piling activity and the temporary nature of the TTS impact, any fish at Goeree Shoal that experience TTS are expected to recover their ability to perceive sound fully.

VSP during drilling of tieback wells will not result in underwater noise levels above impact thresholds for fish at any of the shoals within the Crux in-field development area.

*Key Ecological Features*

The nearest KEF to the Crux platform location is the ancient coastline at 125 m depth contour. Environmental values associated with the geomorphology of this KEF (e.g. enhanced vertical mixing) will not be affected by underwater noise. Benthic communities such as fish assemblages associated with the continental slope demersal fish communities KEF may be affected by noise generated by the pipelaying activities (e.g. pipelay vessel DP noise) but will not be significantly impacted by noise from piling, VSP at the Crux platform location, or operational noise. Refer to **Threatened Species and Ecological Communities** below for further discussion of noise impacts on fish. Other KEFs are too distant from the project area to be credibly impacted by underwater noise.

**Threatened Species and Ecological Communities**

*Marine Mammals*

Most cetacean species use sound to communicate (e.g. humpback whale calls) or perceive their environment (e.g. echolocation of prey). This reliance on underwater noise, and their high conservation value, makes cetaceans of concern when assessing potential impacts from underwater noise.

Low frequency cetaceans are expected to be most vulnerable to underwater noise from piling and VSP due to the frequency spectra of these noise sources overlapping the functional hearing range of these species (approximately 7 Hz to 30 kilohertz (kHz)), and the relatively high intensity of the noise sources. Several low frequency cetaceans (blue, humpback, sei, fin and Bryde's whales) were identified as potentially occurring within the project area (**Section 6.5.6.1**). Noise monitoring in the Timor Sea for the Barossa development indicated pygmy blue and Bryde's[10] whales are the most likely to occur (McPherson et al. 2016). Detection of calling low-frequency cetaceans calls were not constant, but occurred sporadically, often in groups or sets of calls. Humpback, southern right and Antarctic minke whales are considered to be low frequency cetaceans. These three species were identified by the Protected Matters search tool report but are not likely to occur within the Timor Sea based on known distribution data.

The noise assessment (**Appendix I**) indicated that the low frequency cetacean instantaneous peak thresholds (i.e. the $L_p$ from a single hammer strike) for PTS and TTS will not be exceeded at any range. The instantaneous behavioural disturbance threshold for a single hammer strike is exceeded out to a radius of 2.7 km.

The cumulative (i.e. 24-hour) PTS and TTS thresholds for low frequency cetaceans are exceeded at 17.3 km and 57.8 km respectively. These thresholds are highly conservative as they are based on a worst-case hammer size. Shell considers it unlikely that such a hammer will be used during piling. These thresholds are also highly conservative, as they rely on the cetacean remaining within the threshold radius for the duration of the entire 24-hour period. This is considered very unlikely, as low frequency cetaceans in the area are typically migrating and would be expected to move away from uncomfortable stimuli (i.e. high noise levels). Behavioural responses of cetaceans exposed to acoustic disturbance shows typical behavioural response is to move away from unpleasant stimuli. Several species of cetacean, including humpback and minke whales, have been shown to avoid high intensity low frequency sound (Dunlop et al. 2013, Kvadsheim et al. 2017, Sivle et al. 2015). The oceanic low frequency cetaceans that may occur within the Crux project area are expected to be able to move away from the piling noise rapidly. For example, speeds of sei whales and blue whales have been estimated at > 6 km/hr, and individual animals can easily exceed 100 km in a 24-hour period (Double et al. 2014, Prieto et al. 2014) and hence move away from the piling before the time-based PTS and TTS are exceeded. Considering the expected low utilisation of the Crux project area by low frequency cetaceans, avoidance behavioural responses and nature of the piling activity, no low frequency cetaceans are expected to be exposed to noise levels exceeding the 24-hr PTS or TTS thresholds. The nearest known aggregation of whales is the seasonal presence of blue whales in their migratory corridor, which lies approximately 268 km north-west of the Crux platform. Given this distance is well beyond the range at which PTS or TTS may occur, blue whales will not be significantly impacted by piling noise or VSP.

Mid frequency cetaceans are also vulnerable to underwater noise, although their hearing range means they are more vulnerable to noise frequencies overlapping their functional hearing range (approximately 150 Hz to 160 kHz). Mid frequency cetaceans include most toothed whales, dolphins and porpoises; a number of species of mid frequency cetaceans were identified as potentially occurring within the vicinity of the project area (**Section 6.5.6.1**). Noise monitoring in the Timor Sea indicates mid-frequency cetaceans are present year-round (R. Clarke, pers. comm.; McPherson et al. 2016).

[10] McPherson et al. (2016) distinguish Omura's whale (*Balaenoptera omurai*) as a distinct species from Bryde's whale (*B. edeni*), however the taxonomy of Omura's whale is unclear. *B. omurai* is a recent description. Many authorities (including the DoEE) do not make any distinction between *B. omurai* and *B. edeni* and retain *B. edeni* as this species name has priority. As such, this OPP refers only to *B. edeni*, with this classification including *B. omurai*.

The noise assessment (**Appendix I**) indicated that mid frequency cetaceans' instantaneous peak thresholds (i.e. the $L_p$ from a single hammer strike) for PTS and TTS will not be exceeded at any range. The cumulative (i.e. 24-hour) PTS and TTS thresholds for low frequency cetaceans are exceeded at 14 km and 56.9 km respectively. As with the low frequency cumulative thresholds, these PTS and TTS thresholds are highly conservative, as they rely on the cetacean remaining within the threshold radius for the duration of the entire 24-hour period. This is considered very unlikely, as mid frequency cetaceans in the area are highly mobile and would be expected to move away from uncomfortable stimuli (i.e. high noise levels). The instantaneous behavioural disturbance threshold for a single hammer strike is exceeded out to a radius of 2.7 km.

The noise assessment (**Appendix I**) did not indicate that VSP or drilling would exceed any of the low or mid frequency cetacean impact thresholds defined for continuous noise at any range. Vessel DP noise was predicted to exceed the low frequency cetacean cumulative (24-hour) TTS threshold at a range of 350 m and the low frequency behavioural impact threshold at a range of 1.6 km. Low-frequency cetaceans are highly unlikely to remain within these ranges for a 24-hour period, and these impacts are not considered credible.

Based on the results of the noise assessment, the cetacean species that may occur within the project area and the controls Shell will implement, potential impacts are expected to consist of behavioural disturbance only. This behavioural disturbance is likely to consist of avoidance of areas of high noise intensity, which may inhibit other behaviours such as feeding. Behavioural will be restricted in time to relatively short periods when high noise intensity activities are occurring (e.g. piling and VSP). Following cessation of noise generation, animal behaviour is expected to return to normal. Following implementation of controls (e.g. piling “soft start-up”), potential impacts such as mortality, injury, PTS and TTS are considered very unlikely to occur.

*Marine Reptiles*

Marine reptiles such as turtles and sea snakes are not known to be particularly sensitive to underwater noise. Research on marine turtles suggests that functional hearing is concentrated at frequencies between 100 and 600 Hz (which is a subset of the low frequency cetacean range). Several turtle species were identified as likely to occur within the project area (**Section 6.5.6.2**), although no habitat critical to the survival of the species or BIAs overlap of occur near the project area. The water depth and benthic habitat within the project area is typically too deep for turtle foraging for several species (e.g. Hays et al. 2001; Polovina et al. 2003), although species that eat primarily pelagic prey (e.g. leatherback and juvenile green turtles) may forage for pelagic prey. As such, turtles are expected to occur only at low densities within the project area and are likely to be transiting the area rather than foraging, breeding or nesting (although foraging at the relatively shallow shoals within the in-field development area may occur).

The noise assessment (**Appendix I**) indicated that none of the noise sources that may arise from the Crux project would not exceed the instantaneous threshold for permanent injury of fatality, nor the behavioural impact threshold, for marine turtles or sea snakes at any range. The 48-hour cumulative PTS threshold for turtles is exceed out to a range of 390 m for piling noise, however continuous piling activities will not occur for 48 consecutive hours. PTS for marine turtles is not considered credible.

While there are no defined continuous noise (e.g. drilling) thresholds for turtles, the potential risk of mortality or injury at a range of distances (i.e. near – tens of metres, intermediate – hundreds of metres, and far – thousands of metres) is considered to be low (**Table 8-16**). The potential for impairment (including recoverable injury, TTS and masking) is also low, with the exception of masking where there is a high and moderate risk at near and intermediate distances, respectively. With respect to potential behavioural impacts associated with drilling, there is considered to be a moderate risk at near and intermediate distances (localised within hundreds of metres from source) and a low risk further afield (**Table 8-16**). Considering this, noise associated with drilling of the foundation wells is highly unlikely to impact turtles that may be foraging at any of the shoals within the Crux in-field development area, considering the nearest shoal is 13 km from the Crux platform and well beyond the predicted area of impact.

There is a low risk of potential behavioural or masking impacts to individual turtles that may be foraging at the shoals within the in-field development area from noise associated with drilling of tieback wells (> 1 km from the shoals) (**Table 8-16**). While foraging may occur at these shoals, the waters have not been identified as habitat critical to the survival of turtle species or BIAs in the Recovery plan for marine turtles in Australia 2017-2027 (June 2017) (Commonwealth of Australia 2017b).

VSP during drilling of the tieback wells will not result in underwater noise levels above impact thresholds for turtles at any of the shoals within the Crux in-field development area.

Based on the results of the noise assessment, potential impacts to marine reptiles will be restricted to short term behavioural disturbance to animals in close proximity to high intensity noise sources. Given the expected low density of turtles within the project area this potential impact would only affect a relatively small portion of turtle populations in the region. Recovery from behavioural disturbance is expected to occur immediately once the noise emission is ceased.

*Fish, Sharks and Rays*

The project area is not expected to host highly abundant or diverse assemblages of fishes or sharks and rays. Whale sharks occur within the project area (e.g. traversing the open waters within or surrounding the project area during migration to/from aggregation off Ningaloo Reef) and a BIA for whale sharks overlaps with the project area. However, it is expected that whale shark presence within the project area would not be in significant numbers as there is no main aggregation area within the vicinity of the project area, and their presence would be transitory and of a short duration. This is consistent with tagging studies of whale shark movements which show continual movement of whale sharks in deeper, open offshore waters (Meekan and Radford 2010). Given the contrast to the feeding behaviour off aggregation areas such as Ningaloo Reef, the BIA is unlikely to be a dedicated foraging area; rather, it is likely to be a broad area within which migratory movements can be expected. This is consistent with the Conservation Advice (DoE 2015l) for this species which indicates this BIA up the north west coast is a migration corridor than significant foraging habitat. There are no constraints preventing whale sharks from moving away from the project area (e.g. shallow water or shorelines).

Whale sharks forage on plankton (as well as small fish), and high intensity underwater noise has been shown to result in some taxa within zooplankton communities. Recent observations by McCauley et al. (2017) provides evidence of considerable mortality of crustacean zooplankton (e.g. copepods and nauplii larval stage of crustaceans) over short timeframes. However, longer term impacts may be much less discernible due to the high turnover of planktonic communities and the movement of water masses. Modelling studies by the CSIRO indicate that planktonic communities are highly dynamic and have the potential to recover rapidly following disturbance (Richardson et al. 2017). As a result, impacts to zooplankton, which are of short duration, will not negatively affect whale sharks moving through the area. Note that small crustacean zooplankton comprise only part of whale shark diets, with larger plankton and nekton (e.g. krill and baitfish) forming a part of the species' diet (Colman 1997). Whale sharks are not considered to be particularly vulnerable to noise related impacts (refer to **Underwater Noise Impact Thresholds**; see **Other Fauna**).

The noise assessment (**Appendix I**) predicted that no exceedance of the permanent injury threshold for any category of fish (**Table 8-15** and **Table 8-16**) would occur under any of the noise scenarios considered. The noise modelling study results indicated piling noise may exceed the 48 hour cumulative recoverable injury threshold for fish with a swim bladder at a range of 1 km. Given the benthic habitats within 1 km of the piling location are relatively flat unconsolidated soft sediments, which are widely distributed in the region, fish are expected to be within the 1 km radius in low densities only. Fish within this 1 km radius are expected to move away from the source of noise if it was harmful. Once piling is completed, any displaced fish may return.

The cumulative TTS for piling noise may occur out to a range of 13.4 km, which overlaps the range to the nearest shoal (Goeree Shoal). Noting that the study results are conservative (i.e. likely to over-estimate received sound levels) due to the assumption regarding the heaviest hammer weight, TTS of fish may occur within 13.4 km of the pile. Fish, including fish associated with Goeree Shoal, would be expected to recover fully following the cessation of piling noise.

Modelling study results indicated VSP noise did not exceed any of the mortality or impairment thresholds for fish, sharks and rays at any range. Impacts to VSP on fish will be restricted to short-term behavioural disturbances during VSP operations. Resumption of normal behaviour is expected to occur once VSP operations cease.

Many species of pelagic and demersal fish have a planktonic larval stage. Experiments have shown mixed results of larval stages to undertaker noise. For example, experiments on several species of fish larvae and lobster larvae did not detect significant effects as a result of high intensity impulsive noise (Bolle et al. 2012; Day et al. 2016; Payne et al. 2009).

Based on the results of the noise assessment, the potential impacts to fish and sharks and rays are expected to be a minor, short-term behavioural disturbance. Given the habitat within the project area does not host particularly abundant or diverse fish assemblages, the potential for PTS and TTS is considered to be very low. Fish assemblages at the nearest shoal, Goeree Shoal, may be exposed to piling noise approaching the TTS threshold, however given piling activities are expected to occur for less than 24 consecutive hours, the potential for impact is considered to be low.

### 8.4.3.4 Risk and Impact Summary and Key Management Controls

Table 8-19: Underwater Noise Evaluation of Impacts and Risks

| **Project Component/ Activity** | **Environmental Value/Sensitivity** | | | | **Evaluation – Planned** | | |
|---|---|---|---|---|---|---|---|
| | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Magnitude** | **Sensitivity** | **Residual Impact** |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from underwater noise generated during the Crux project, including:<br>• piling<br>• VSP<br>• operations, and<br>• vessels | | X | X | | Minor | Medium | Minor |
| ***Key Management Controls*** | | | | | | | |
| Any VSP activities conducted at the development well will comply with 'Standard Management Procedures' set out in EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic | | | | | | | |

| |
|---|
| Exploration and Whales: Industry Guidelines (DEWHA 2008c) (or the contemporary requirements at the time of the activity), specifically:<br>• pre-start-up visual observations. Visual observations for the presence of whales by a suitably trained crew member will be carried out at least 30 minutes before the commencement of VSP.<br>• start-up and normal operating procedures, including a process for delayed start-up, should whales be sighted. Visual observations by trained crew should be maintained continuously.<br>• night time and low visibility procedures.<br>Pile driving activities conducted for the Crux platform foundations will comply with 'Standard Management Procedures' set out in EPBC Act Policy Statement 2.1 – Interaction between Offshore Seismic Exploration and Whales: Industry Guidelines, specifically:<br>• pre-start-up visual observations. Visual observations for the presence of whales by a trained marine mammal observer will be carried out at least 30 minutes before the commencement of pile driving.<br>• start-up and normal operating procedures, including a process for delayed start-up, should whales be sighted. Visual observations by a trained marine mammal observer should be maintained continuously.<br>• shut-down procedures. Piling will be stopped should whales come within 500 m of the pile driving barge.<br>• night time and low visibility procedures.<br>• in addition to the 'Standard Management Procedures' identified above, Shell will commit to at least one trained marine mammal observer being present on the pile driving barge for the duration of pile driving activities for the Crux platform foundations.<br>Maintenance of a minimum 1 km buffer from shoals within the in-field development area (**Figure 5-3**). |

### 8.4.3.5 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the underwater noise aspect of the Crux project are summarised in **Table 8-20**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the underwater noise aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the underwater noise aspect of the Crux project is provided below.

Table 8-20: Acceptable Levels of Impacts and Risks from Underwater Noise

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Ecosystems, Communities and Habitats | Benthic communities | No significant impacts to benthic habitats and communities.<br>Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | Yes. Potential noise-related impacts will be concentrated around the Crux platform during piling. Biota associated with the communities around the Crux platform are broadly distributed in the wider region and are not considered to be unique or highly sensitive. Underwater noise from VSP undertaken during tieback well drilling will not result in significant impacts to benthic communities in the Crux in-field development area. |
| | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of cover of benthic habitats and communities at named banks or shoals as a result | Yes. Modelling of underwater noise levels from piling indicates PTS will not occur at any of the shoals in the Crux in-field development area. TTS, from which fish are expected to recover, may credibly occur at the nearest shoal (Goeree Shoal) if a |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| | | of indirect/offsite[11] impacts associated with the Crux project. | heavy piling hammer is used and piling is conducted for 48 consecutive hours. Underwater noise from VSP undertaken during tieback well drilling will not exceed impact thresholds at any shoals. |
| | Key Ecological Features | No significant impacts to environmental values of KEFs. | Yes. Underwater noise above impact thresholds for fish will not credibly occur at the continental slope demersal fish communities KEF. The fish assemblages that are the key environmental value of this KEF will not be significantly impacted. |
| Threatened Species and Ecological Communities | Key fauna species | No mortality or injury of threatened or migratory MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory MNES fauna. | Yes. Potential noise-related impacts will be concentrated around the Crux platform during piling. This area is not important habitat for threatened or migratory MNES that may be impacted by underwater noise, such as cetaceans and marine turtles. Instantaneous PTS and TTS impact thresholds for these species will not be exceeded. Cumulative 24-hr PTS and TTS thresholds for low frequency cetaceans, however it is very unlikely that a low frequency cetacean would remain in the area long enough to result in PTS or TTS. Piling is a discrete, short duration activity; other sources of noise will not result in significant impacts to threatened and migratory MNES.<br>Potential impacts to foraging turtles at the shoals within the in-field development area from drilling of tieback wells outside the defined 1 km buffer are restricted to temporary behavioural or masking impacts. These potential impacts will not result in significant impacts to either the individual turtle or at a population level and do not impact identified BIAs or habitat critical to the survival of the species. Drilling is a discrete and relatively short duration activity. |
| Socio-economic and Cultural Environment | Commercial fisheries | No negative impacts to exploited fisheries resource stocks which result in a demonstrated direct loss of income. | Yes. Potential impacts to fish from underwater noise are restricted to TTS and behavioural disturbance. These potential impacts will not result in impacts to commercial fishers. |

[11] As defined in the Matters of National Environmental Significance – Significant impact guidelines 1.1 (DoE 2013a).

**Principles of ESD**

The risks and impacts from underwater noise associated with the Crux project are consistent with the principles of ESD based on:

- the environmental values/sensitivities within the project area are not expected to be significantly impacted, and
- the precautionary principle has been applied, and studies undertaken where knowledge gaps were identified.

**Relevant Requirements**

Management of the impacts and risks from underwater noise associated with the Crux project are consistent with relevant legislative requirements, including:

- application of relevant guidelines:
  - VSP operations and pile driving activities are consistent with the requirements of *EPBC Policy Statement – Interaction between offshore seismic exploration and whales* (DEWHA 2008c)
  - noise assessment consistent with the recommendations of the *Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing* (NOAA 2018), and
  - noise assessment consistent with the recommendations of the *Sound exposure guidelines for fishes and sea turtle* (Popper et al. 2014) was undertaken.
- management of impacts and risks are consistent with policies, strategies, guidelines, conservation advice, and recovery plans for threatened species (**Table 8-21**).

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates significant impacts[12] to threatened and migratory species will not credibly result from the planned direct impacts from the underwater noise aspects of the Crux project. Impacts are likely to be restricted to temporary behavioural disturbance of individual animals (most likely low frequency cetaceans).

Alignment of the Crux project with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided in **Table 8-21**.

*Commonwealth Marine Environment*

The impacts and risks from underwater noise associated with the Crux project on the ancient coastline at 125 m depth contour KEF and continental slope demersal fish communities KEF do not significantly affect the environmental values of these KEFs.

[12] As described in Matters of National Environmental Significance - Significant impact guidelines (DoE 2013a)

Table 8-21: Summary of Alignment of the Impacts and Risks from Underwater Noise associated with the Crux Project with Relevant Requirements for EPBC Threatened Fauna

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| Marine mammals | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Underwater noise emissions | The impact assessment indicates that the impacts and risks from underwater noise to threatened or migratory marine mammals are likely to be restricted to behavioural disturbances of individual animals. PTS and TTS of threatened or migratory marine species is considered very unlikely. As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | Conservation advice on sei whale (*Balaenoptera borealis*) (DoE 2015c) | Anthropogenic noise and acoustic disturbance | The risk of anthropogenic noise to cetaceans will be managed in accordance with:<br>• VSP operations and pile driving activities are consistent with the requirements of *EPBC Policy Statement – Interaction between offshore seismic exploration and whales* (DEWHA 2008c).<br>A noise assessment consistent with the recommendations of the *Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing* (NOAA 2018) was undertaken. |
| | Conservation advice on fin whale (*Balaenoptera physalus*) (DoE 2015d) | Anthropogenic noise and acoustic disturbance | |
| | Conservation management plan for the blue whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015–2025 (Commonwealth of Australia 2015a) | Noise interference | |
| | Conservation advice on humpback whale (*Megaptera novaeangliae*) (DoE 2015b) | Noise interference | |
| Marine reptiles | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (Table 7-1) | Underwater noise emissions | The impact assessment indicates that the impacts and risks from underwater noise to threatened or migratory marine turtles are likely to be restricted to behavioural disturbances of individual animals. PTS and TTS of threatened or marine turtles is not considered credible. As such, the Crux project does not exceed any of the significant impact criteria for Threatened and Migratory marine species provided in **Table 7-1**. |
| | Recovery Plan for Marine Turtles in Australia 2017–2027 (Commonwealth of Australia 2017b) | Noise interference | A noise assessment consistent with the recommendations of the S*ound exposure guidelines for fishes and sea turtle* (Popper et al. 2014) was undertaken.<br>The waters within the Crux in-field development area have not been identified as habitat critical to the survival of turtle species or BIAs in the Recovery plan for marine turtles in Australia 2017-2027 (June 2017) (Commonwealth of Australia 2017b). |
| Sharks and rays | Conservation advice on whale shark (*Rhincodon typus*) (DoE 2015l) | Habitat disruption from mineral exploration, production and transportation | A noise assessment consistent with the recommendations of the S*ound exposure guidelines for fishes and sea turtle* (Popper et al. 2014) was undertaken. This considered the potential impacts of underwater noise on whale sharks. |

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| Commonwealth marine area | Significant Impact Guidelines for the Commonwealth marine environment (**Table 7-1**) | Underwater noise | The impact assessment indicates that the underwater noise aspect of the Crux project will not exceed the Commonwealth marine environment significant impact criteria provided in **Table 7-1**. |

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from underwater noise associated with the Crux project determined the residual impact and risk ranking was minor (**Table 8-19**). As outlined above, the acceptability of the impacts and risks from underwater noise associated with the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are minor. Shell considers residual impacts of minor or lower to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to the underwater noise aspect of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from underwater noise associated with the Crux project to be acceptable.

### 8.4.3.6 Environmental Performance Outcomes

**Threatened Species and Ecological Communities**

No mortality or injury of threatened and migratory MNES species as a result of underwater noise from the Crux project.

### 8.4.4 Atmospheric Emissions

#### 8.4.4.1 Project Context

As part of early concept engineering, there are a range of inherent design and operational efficiencies that have been incorporated that support GHG efficiency gains, including:

- selection of NNM platform as opposed to FPSO concept, which contribute significant emissions reduction compared to this alternative
- leak detection and repair program to find and control fugitive emissions, and
- the selection of TEG off gas flaring over venting based on the approximately 25-fold improved GHG footprint of flaring hydrocarbons versus venting hydrocarbons.

After selecting the NNM concept the remaining atmospheric emissions as a consequence of the Crux project are:

- Emissions from operating the Crux facility including:
  - combustion emissions from power generation and processing facilities
  - periodic flaring of gas during commissioning/start-up and shutdown activities. A continuous small pilot flame will be necessary on the flare during operations for safety and GHG intensity reasons. This will comprise a continuous flow of small quantities of purge gas and off gas from gas dehydration.
  - disposal of TEG regeneration off gas stream to flare
  - disposal of separated reservoir CO2 in the feed gas
  - transportation, such as vessel and helicopter movements, and
  - fugitive emissions.
- Emissions from installing the Crux facility; and
- Emissions associated with Crux products at the Prelude facility (following the Crux facility coming online) including:
  - Combustion emissions from power generation and processing facilities
  - disposal of separated reservoir CO2 in the feed gas
  - periodic flaring of gas
  - transportation, such as vessel and helicopter movements, and
  - fugitive emissions.

Refer to **Section 5.7.5** for additional information on these sources.

This section evaluates the environmental impacts and risks associated with the atmospheric emissions aspect of the Crux project.

<u>Summary of other legislative requirements</u>
Management of the impacts from atmospheric emissions associated with the Crux project are consistent with relevant legislative and other requirements, including:

- compliance with international conventions, including:
  - MARPOL Annex VI: Regulations for the prevention of air pollution from ships
  - The Paris Agreement as agreed under the United Nations Framework Convention on Climate Change at the 21st Conference of the Parties in 2015
- compliance with Australian legislation and requirements, including:

- *EPBC Act Policy Statement - 'Indirect consequences' of an action: Section 527E of the EPBC Act*
- *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983 including Marine Order 97 (Marine Pollution Prevention – Air Pollution)*
- relevant requirements of the National Pollutant Inventory (NPI) NEPM, National Greenhouse and Energy Reporting Act 2007, and National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (or contemporary requirements at the time).

- implementation of recognised industry standard practice, such as:
  - preventative maintenance system
  - optimise flaring to enable the safe and efficient operation of the facility, and
  - equipment selection in design, to achieve emissions efficiencies.

In conclusion, the legislative framework for managing consequences of atmospheric emissions from offshore petroleum activities and emissions attributable to the Crux project are well-developed and comprehensive because they cover prevention, abatement, and offset of emissions in a structured and predicatable way.

Description and Evaluation of Impacts and RisksGiven the offshore remote context, environmental sensitivities within the following groups may be impacted by atmospheric emissions arising from the Crux project, including:

- physical environment (air quality), and

**Physical Environment**

*Air quality in the In-field Development Area*

Gaseous emissions arising from the Crux project are anticipated to include atmospheric emissions of sulphur compounds (typically described as $SO_X$ and $H_2S$), $NO_X$, carbon monoxide (CO), $CO_2$ and particulates (typically described as $PM_{10}$ or $PM_{2.5}$). It is expected there will be some fugitive emissions, described as VOCs, from non-point source releases.

As described previously in **Section 5.7.5**, the majority of atmospheric emissions will be directed through to the operational Prelude FLNG facility. Only a minor (< 6% based on foundation project) proportion is attributable to the Crux project as a back-fill gas supply to Prelude. Therefore, it is important context that the majority (> 90%) of the air emissions profile have been subject to prior assessment and approval through the Prelude FLNG EIS and subsequent EPs. Atmospheric emissions which occur on the Prelude FLNG facility will not be assessed again under this proposal.

The quantities of gaseous emissions associated with the Crux project are relatively small and will, under normal circumstances, be quickly dissipated into the surrounding atmosphere through natural dispersion and dilution (e.g. wind, mixing). In general terms, the sensitivity of local air quality in the in-field development area is considered low due to the absence of existing pollution sources and the absence of sensitive receptors. Considering the location of the Crux project in the open ocean, which is well-removed from nearest residential or sensitive populations of the WA coast (> 160 km), and the localised nature of the emissions, it is considered highly unlikely that atmospheric emissions will result in significant impacts to ambient air quality at a local and regional scale. Furthermore, no impacts to the local airshed at the nearest shorelines of Cartier Island (105 km) and Ashmore Reef (155 km), which support foraging and breeding populations of turtles and birds, are expected given the localised nature of the emissions. While not a planned activity, it may be necessary to conduct unplanned venting of hydrocarbon gas (i.e. blowdown) to depressurise the production process onboard the

Crux platform. Under normal circumstances, this hydrocarbon gas is flared. Unplanned venting would only occur if the flare was not available for use. Flaring is preferred to unplanned venting for safety and environmental reasons as:

- uncombusted hydrocarbon gas poses a significant safety risk, and
- unburned methane (the main component of the hydrocarbon gas) is a more potent GHG than carbon dioxide.

Atmospheric emissions will result in a minor deterioration in local air quality. While emissions of GHG will cause an incremental increase in global GHG concentrations, they are not considered to have a determinable local-scale impact. This is further considered in a socio-economic and cultural context in the following sub-section. Taking into account the low sensitivity of the receiving environment subject to local and regional air quality changes (absence of receptors in the open offshore context), the residual impact is concluded to be low.

**Shell's Approach to Mitigation**

**Table 8-22** provides a summary of key management controls that will be applied to manage atmospheric emissions. This includes the commitment that:

- all drilling rigs, vessels and Crux platform (as appropriate to vessel class) will comply with MARPOL Annex VI (Prevention of air pollution from ships), the *Navigation Act 2012*, the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 and subsequent Marine Orders. which requires vessels to have a valid International Air Pollution Prevention Certificate (for vessels > 400 tonnage) and use of low sulphur fuel, when possible;
- flaring during operations will be optimised to enable the safe and economically efficient operation of the facility;
- selection of gas turbine generators during design process considers energy efficient (i.e. low emission) equipment, in alignment with the selected concept;
- TEG off gas will not be vented but sent to the flare for combustion if the flare is ignited; and

**Outcomes of the Evaluation of Atmospheric Emissions**

In conclusion, the evaluation of atmospheric emissions attributable to the Crux project shows that the direct impacts will change the air quality around the Crux location and that that impact will be:

- localised to the Crux location and in-field development area; and
- recoverable within a short timeframe once the facility reaches the end of its field life; and
- insignificant in relation to any environmental value or sensitivity including MNES.

### 8.4.4.2 Risk and Impact Summary and Key Management Controls

Table 8-23: Atmospheric Emissions Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Planned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Magnitude | Sensitivity | Residual Impact |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from atmospheric emissions arising from the Crux project, including:<br>• decline in local or regional air quality, and<br>• contribution to the incremental build-up of GHG in the atmosphere | X | | | X | Minor effect | Low | Minor |
| **Evaluation – Unplanned Risks** | | | | | | | |
| **Project Component/ Activity** | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Significance** | **Likelihood** | **Residual Risk** |
| Unplanned impacts from venting of hydrocarbon gas. | X | | | | Slight | Remote | Negligible |
| ***Key Management Controls*** | | | | | | | |
| All drilling rigs, vessels and Crux platform (as appropriate to vessel class) will comply with MARPOL Annex VI (Prevention of air pollution from ships), the *Navigation Act 2012*, the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsequent Marine Orders. which requires vessels to have a valid International Air Pollution Prevention Certificate (for vessels > 400 tonnage) and use of low sulphur fuel, when possible.<br>Flaring during operations is optimised to enable the safe and economically efficient operation of the facility.<br>Selection of gas turbine generators during design process considers energy efficient (i.e. low emission) equipment, in alignment with the selected concept.<br>TEG off gas will not be vented but sent to the flare for combustion if the flare is ignited.<br>During operations of the Crux facility, regular reviews of GHG opportunities will be reviewed and adopted where appropriate. | | | | | | | |

#### 8.4.4.3 Acceptability of Impacts and Risks

The acceptable level of impact for the receptors that may credibly be impacted or at risk from the atmospheric emissions aspect of the Crux project is summarised in **Table 8-24**. The methods by which this acceptable level was determined, along with a justification as to why it is acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the atmospheric emissions aspect of the Crux project are of an acceptable level.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the atmospheric emissions aspect of the Crux project is provided below.

Table 8-24: Acceptable Levels of Impacts and Risks from Atmospheric Emissions

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Physical Environment | Air quality | No significant impacts to air quality during the Crux project. | Yes. Impacts to air quality from atmospheric emissions during the Crux project will be localised. Given the remoteness of the Crux project area, there is no potential for significant environmental impacts to occur. |

**Principles of ESD**

The risks and impacts from atmospheric emissions from the Crux project are consistent with the principles of ESD based on:

- the environmental resources within the project area are not expected to be significantly impacted, and
- the precautionary principle has been applied, and studies undertaken where knowledge gaps were identified.

**Relevant Requirements**

Management of the impacts and risks from atmospheric emissions associated with the Crux project are consistent with relevant legislative requirements, including:

- compliance with international maritime conventions, including:
  - MARPOL:
  - Annex VI: Regulations for the prevention of air pollution from ships
- compliance with Australian legislation and requirements, including:
  - *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*
    - Marine Order 97 (Marine Pollution Prevention – Air Pollution)
  - relevant requirements of the National Pollutant Inventory (NPI) NEPM, National Greenhouse and Energy Reporting Act 2007, and National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015 (or contemporary requirements at the time).
- implementation of recognised industry standard practice, such as:
  - preventative maintenance system
  - optimise flaring to enable the safe and efficient operation of the facility, and
  - equipment selection in design, to achieve emissions efficiencies.

#### Matters of National Environmental Significance

*Threatened and Migratory Species*
Atmospheric emissions will not credibly result in significant impacts to threatened or migratory species.

*Commonwealth Marine Environment*
The impacts and risks from the atmospheric emissions aspect of the Crux project on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Table 7-1**.

#### Internal and External Context

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

#### Acceptability Summary

The assessment of impacts and risks from atmospheric emissions determined the residual impact and risk ratings were Minor or lower (**Table 8-23**). As outlined above, the acceptability of the impacts and risks from atmospheric emissions associated with the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are minor. Shell considers residual impacts of minor or lower to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to the atmospheric emissions aspect of the Crux project. Based on the points discussed above, Shell considered the impacts and risks from atmospheric emissions associated with the Crux project to be acceptable.

### 8.4.4.4 Environmental Performance Outcomes

#### Physical Environment

No significant decline in air quality at residential or sensitive populations as a result of atmospheric emissions from the Crux project.

Atmospheric emissions associated with all drilling rigs, project vessels and the Crux platform to comply with MARPOL Annex VI requirements.

Atmospheric emissions associated with the project will be consistent with national and international mechanisms for the management of GHG emissions for the life of the project.

### 8.4.5 Greenhouse Gas Emissions

Section 8.4.5 details the environmental impacts from Greenhouse Gas (GHG) emissions from the Crux project and from end-users. There is discussion to put these emissions in context having regard to the applicable legislative frameworks, the predicted total emissions, and relevant background on the relationship between the Prelude and Crux projects.

There follow two impact assessments; one for direct emissions and a second for indirect emissions. Both impact assessments have analysis to support a series of conclusions that can be evidenced from the evaluation. In sum, this section will demonstrate that GHG emissions will be managed to an acceptable level and concludes by setting relevant environmental performance outcomes.

For the purpose of this impact assessment the calculation of GHG emissions has been undertaken to align with the *GHG Protocol Corporate Accounting and Reporting Standard* (GHG Protocol). The GHG Protocol provides requirements and guidance for companies and other organisations preparing a corporate-level GHG emissions inventory, and has been widely accepted, including by various regulatory bodies.

To help delineate direct and indirect emission sources, improve transparency, and provide utility for different types of organizations and different types of climate policies and business goals, three “scopes” (scope 1, scope 2, and scope 3) are defined for GHG accounting and reporting purposes. Scopes 1 and 2 are carefully defined in this standard to ensure that two or more companies will not account for emissions in the same scope.

Scope 1 emissions are direct GHG emissions that occur from sources that are owned or controlled by the company. Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. The Crux project does not have Scope 2 emissions. Scope 3 emissions occur from sources not owned or controlled by the company including the use of sold products.

#### 8.4.5.1 Legislative Frameworks

This section outlines the international and Australian legislative frameworks and policies dealing with GHG emissions.

**International Legislative Framework**

The United Nations Framework Convention on Climate Change (UNFCCC) came into force in 1994 and has now been ratified by 197 nations. The aim of the UNFCCC is to prevent anthropogenic interference with the climate system.

The Kyoto Protocol is an instrument made under the UNFCCC. It operationalises the UNFCCC by committing industrialised countries (Annex I Parties) to limit and reduce GHG emissions. The Protocol is based on the principle of common but differentiated responsibilities: it acknowledges that individual countries have different capabilities in combating climate change, owing to economic development, and therefore puts the obligation to reduce current emissions on developed countries on the basis that they are historically responsible for the current levels of GHG in the atmosphere.

The Paris Agreement is also an instrument made under the UNFCCC, with the central aim of strengthening the global response to the threat of climate change by keeping the global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. It deals with GHG emissions mitigation, adaptation, and finance. The agreement's language was negotiated by representatives of 196 state parties, including Australia, and adopted by consensus on 12 December 2015, before entering in to force in late 2016. Australia has since ratified the Paris Agreement. The Paris Agreement requires each party to:

- volunteer its own Nationally Determined Contributions (NDCs), to report against them annually, and improve them if it is determined that the collective commitment to NDCs is considered ineffective or insufficient to keep global temperature increases to less than 2°C below pre-industrial levels. This allows for variation in emissions reduction performance according to the development status of the country; and
- determine, plan, and regularly report on the contribution that it undertakes to mitigate global warming. No mechanism forces a country to set a specific emissions target by a specific date, but each target should go beyond previously set targets.

Australia has set the following Nationally Determined Contribution under the Paris Agreement. (Source: climatetracker.org – LULUCF means land use, land-use change, and forestry).

| AUSTRALIA | Summary of pledges and targets | |
|---|---|---|
| PARIS AGREEMENT | Ratified | Yes |
| | 2030 unconditional target(s) | 26–28% below 2005 by 2030<br>[4–7% above 1990 levels by 2030 excl. LULUCF]<br>[17-19% below 2010 levels by 2030 excl. LULUCF] |
| | Coverage | Economy-wide, incl. LULUCF |

**National Legislative Requirements**

Project Approvals

In Australia, the Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act) is the primary legislation that aims to provide an effective regulatory framework for petroleum exploration and recovery in offshore areas of Australia. This legislation provides for grant of titles for exploration and production of Australia's natural resources. The grant of titles, along with other approval documents, such as the OPP requirement and the requirement for approval of a Field Development Plan (FDP), provide Government with opportunities to decide what resource opportunities can be pursued within Australia.

GHG Emissions

Australia's commitments under the Paris Agreement are delivered through the primary legislation for emissions management; the National Greenhouse and Energy Reporting Act 2007 (Cth) (NGER Act). The NGER Act provides a single, national framework for the reporting and distribution of information related to GHG emissions, GHG projects, energy production and energy consumption to meet the following objectives:

- inform government policy;
- inform the Australian public;
- help meet Australia's international reporting obligations;
- assist Commonwealth, state and territory government programmes and activities, and
- avoid duplication of similar reporting requirements in the states and territories.

Emissions Reporting

Under the NGER Act facility operators are required to report on direct GHG emissions, energy production and energy consumption, enabling the capture of data on energy flows and transformations occurring throughout the economy. The NGER Act is aligned with the GHG Protocol in defining Scope 1 and 2 emissions.

Safeguard Mechanism

The safeguard mechanism provides a framework for Australia's largest emitters to measure, report and manage their emissions. It was established to ensure that emissions reductions delivered through the Emissions Reduction Fund are not displaced significantly by GHG emissions over and above business-as-usual- levels elsewhere in the economy. It does this by requiring large facilities, whose net emissions exceed the safeguard threshold of 100,000 tonnes of $CO_{2\text{-}e}$ per annum, to keep their net emissions at or below emissions baselines set by the Clean Energy Regulator. Key elements of the mechanism include:

- safeguard facilities must meet the reporting and record keeping requirements of the NGER Act, including the Clean Energy Regulator's requirements for audits prior to baseline setting or to check compliance management;
- if a safeguard facility is likely to exceed its baseline, the responsible emitter must act, including by purchasing and surrendering Australian Carbon Credit Units (ACCUs) to offset excess emissions; and
- penalties for non-compliance.

Under the Safeguard Mechanism annual reports are available of scope 1 & 2 emissions from facilities operated by corporations in the preceding year. In the 2018-2019 reporting period 418 companies reported a total of over 338 Mt in scope 1 emissions with the average corporation responsible for facilities emitting 810 Kt. Reported scope 1 emissions ranged from 3 tonnes to 42.7 Mt with 84% of corporations emitting less than 0.5 Mt.

Emissions Reduction

Building on the initial Emissions Reduction Fund announced in 2016, in 2019 the Commonwealth allocated an additional $3.5 billion to deliver on Australia's 2030 Paris Agreement commitments through measures including:

- an additional $2bn Climate Solutions Fund to top up the Emissions Reduction Fund by providing funding for verifiable emissions reductions projects;
- direct investment in major projects, including Snowy 2.0 and the Marinus Link interconnector; and
- the National Electric Vehicle Strategy.

Other Commonwealth environmental legislation

In addition, as set out in section 1, there is general environmental protection legislation that applies to Scope 1 & 2 GHG emissions. Under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cth), the environmental impacts and risks of a project must be identified. The EPBC Act is the Commonwealth's key piece of environmental legislation and requires consideration of environmental impacts where impacts are likely to be significant.

The consideration of impacts under the EPBC Act includes having regard to events or circumstances that are "impacts"[13], including direct and indirect consequences. Various

[13] Impact is defined in s527E of the EPBC Act.

supporting policies provide guidance on interpretation of these requirements, including *EPBC Act Policy Statement - 'Indirect consequences' of an action: Section 527E of the EPBC Act.*

**State legislation and policy**

In August 2019, the Western Australian government released its *Greenhouse Gas Emissions Policy for Major Projects*. This policy is designed to guide decision-making for major projects that are assessed by the EPA (and accordingly is not directly relevant to the Crux project). The policy contains a commitment to work with all sectors of the WA economy towards achieving net zero greenhouse gas emissions by 2050. The Crux project is outside of the Western Australian jurisdiction.

### 8.4.5.2 Overview of GHG Emissions in the Crux Project

**Project background - relationship between Crux and Prelude**

As outlined in **Section 1.1**, Shell Australia Pty Ltd (Shell), is the proponent for the project in its capacity as operator of the Crux Joint Venture (JV) (Shell, SGH Energy and Osaka Gas). Gas produced by the Crux JV will be processed into LNG, LPG and condensate at the Prelude FLNG facility under processing agreements to be concluded with the Prelude JV (Shell, Inpex, KOGAS and OPIC). Shell is also the operator of the Prelude FLNG facility in its capacity as operator of the Prelude JV. Shell, as a subsidiary of Royal Dutch Shell plc, is a member of the Shell group of companies (and in this section 6, where there is reference to Shell's activities globally, the term "Shell Group" is used).

The Prelude FLNG project was approved under the EPBC Act in 2015 (EPBC 2008/4146). It is noted that the Crux JV will contract to use processing capacity available in the Prelude FLNG facility as production from the Prelude field begins to decline. Accordingly, Crux gas will be processed within the existing production capacity of Prelude (approved with a designed production capacity of 3.6 Mtpa of LNG, 0.4 Mtpa of LPG and 1.3 Mtpa of condensate).

**Relationship between Crux and Prelude Emissions**

The decision to approve the Prelude activity gave permission to discharge 2.3 Mtpa $CO_{2\text{-e}}$ over a 25-year period. This included venting of reservoir CO2, fuel combustion, flaring and fugitive emissions (as set out in the Prelude Environmental Impact Statement section 6.8). Prelude FLNG commenced operations in 2016 and so the approval for these emissions is in place until 2041.

Crux is planned to come online in 2025 and feed gas to Prelude until 2045. So, when Crux comes online, Prelude will have been operational for 9 years of its approval period. The remaining 16 years of emissions from Prelude have been assessed and approved, up to 2.3 Mpta $CO_{2\text{-e}}$ and are therefore not assessable again under this OPP. Crux may extend the life of Prelude to 2045 (expected) or 2065 (extended) and so this OPP does include assessment of the emissions associated with the Crux project, at Prelude, after 2041. The emissions approval coverage described above is shown in Figure 8-5.

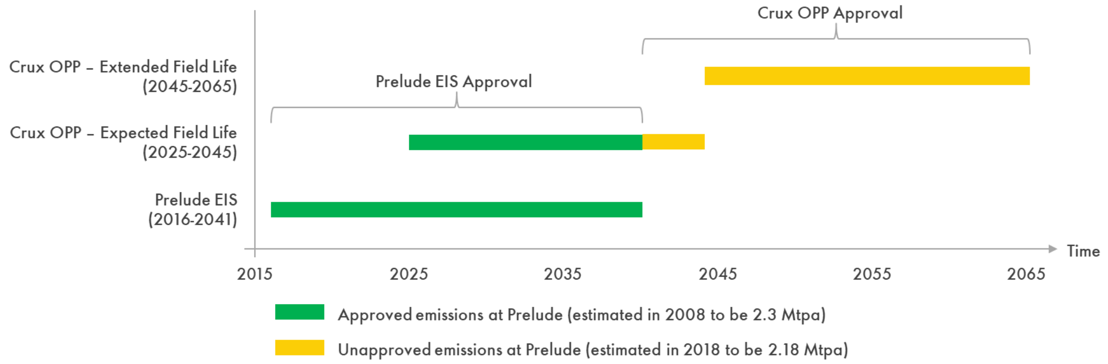



Figure 8-5: GHG emissions approvals coverage at the Prelude facility

**Shell Australia Carbon Strategy**

In its Australian business, Shell currently maintains and implements a Carbon Strategy and Implementation Plan vehicle to identify carbon dilemmas and opportunities across the Australian businesses (including the Crux Project), developing innovative resolutions at a global level and integrating them across Shell Australia assets, projects and functions. The Carbon Strategy consists of 3 pillars:

1. Reduce – emissions from Shell operated ventures reduced to ALARP;
2. Develop – new energies and new fuels, e.g. solar and hydrogen; and
3. Mitigate – via Nature Based Solutions or alternative options.

The implementation of the plan has 3 focus areas with 6 underlying work streams;

1. People focus (a. Committed Leadership and b. Empowered Employees)
2. Delivery focus (a. Assets and Projects ALARP and b. Pan Australia Opportunities)
3. External focus (a. Advocacy and b. Joint Venture & Industry Partnership).

The objectives of the strategy are to:

a) develop a clear action plan to manage GHG risks and opportunities; and
b) provide aligned carbon value drivers and objectives; and
c) implement the identified actions into core business processes; and
d) develop consolidated carbon resources.

**Emissions Reduction in Concept Select and Design**

The Crux project was originally a Floating Production Storage and Offloading (FPSO) concept. This would have required duplication of much of the equipment to refine gas that is already found on Prelude. A GHG Energy Management Plan (GHGEMP) is an internal Shell requirement to drive project teams to target lower emitting concepts and technologies. As a result, the Crux project incorporates a range of inherent design and operational efficiencies committed to during the front-end engineering phase which reduce GHG intensity, including:

- selection of a Not-Normally Manned (NNM) platform concept reduces GHG emissions intensity from upstream operations by 80%;

- the selection of triethylene glycol (TEG) off-gas flaring over venting based on the approximately 9-fold[14] improved GHG footprint of flaring hydrocarbons versus venting hydrocarbons;
- confirmation of a 3x50% Gas Turbine Generator (GTG) configuration with the spare GTG in a "cold" operationally ready status. The alternative of having an online spare GTG would result in 27% additional fuel usage;
- optimisation of the TEG Regeneration System has reduced the requirement for stripping gas that is used to aid dehydration. This has reduced overall TEG off-gas flaring by 15%;
- inclusion of energy efficient equipment in the platform design (pumps, fans) has resulted in a 15% reduction in overall electrical demand for the Crux facility; and
- leak detection and repair program to find and control fugitive emissions.

After selecting the NNM concept the remaining GHG emissions sources come from; Crux installation, Crux operations, Prelude operations (following the Crux facility coming online), transportation to import facility, and finally the end-user combustion of the gas overseas. **Table 8-25** provides a description of the emissions included in each of these sources and the basis upon which the total amount of GHG emissions has been calculated. The table also breaks down the total GHG emissions from the Crux project by each source in the expected life and extended life cases.

[14] When 1 tonne gas is combusted, it is converted to 2.7t $CO_2$ (in $CO_{2\text{-}e}$), 0.1t $CH_4$ (in $CO_{2\text{-}e}$) and 0.03t $N_2O$ (in $CO_{2\text{-}e}$) (based on coal seam gas). Therefore, the ratio between $CO_{2\text{-}e}$ if a tonne of gas is vented versus flared is approximately 9:1.

Table 8-25: Description of Emissions from the Crux Project and Basis of Calculation of Emissions

| Emission source | Party | Description | Basis of calculation | Estimated Annual Average Emissions ($CO_2$-e Mtpa) | Estimated Total Emissions: Expected Life (20 years) ($CO_2$-e Mt) | Estimated Total Emissions: Extended Life (40 years) ($CO_2$-e Mt) |
|---|---|---|---|---|---|---|
| Crux installation | Crux JV | The use of energy in constructing the Crux facility resulting in the discharge of GHG emissions. | The sum of emissions from construction of the facility and vessels used to install the wells and facility. Installation activities are predicted to take no more than 2 years. Therefore, only total emissions predicted from these activities are provided in the table as the annual emissions are a one-off event rather than an annual contribution to GHG emissions. Installation occurs once rather than annually so an annualized average is not representative of the emissions from this action. | N/A | 1 | 1 |
| Crux operations | Crux JV | Emissions from operating the Crux facility including:<br>- emissions from power generation, processing facilities, flaring etc.<br>- disposal of reservoir $CO_2$<br>- vessel and helicopter emissions<br>- fugitive emissions | The average annual emissions based on known combustion efficiencies from power generation (0.019 $CO_{2\text{-}e}$ Mtpa), fugitive emissions (0.046 $CO_{2\text{-}e}$ Mtpa), and future compression (0.282 $CO_{2\text{-}e}$ Mtpa). For the purpose of the impact assessment it is assumed compression is required in every year of operation. This is a conservative assumption and is not likely to occur. The expected field life of Crux is 20 years with an extended field life of 40 years[15]. | 0.347 | 7 | 14 |

[15] The extended field life of Crux is unknown and subject to future investment decisions. A 40-year duration is used solely as the basis for calculating possible future GHG emissions and should not be interpreted as either a firm commitment to extending asset life or as a firm end point for the facility.

| Emission source | Party | Description | Basis of calculation | Estimated Annual Average Emissions ($CO_2$-e Mtpa) | Estimated Total Emissions | |
|---|---|---|---|---|---|---|
| | | | | | Expected Life (20 years) ($CO_2$-e Mt) | Extended Life (40 years) ($CO_2$-e Mt) |
| Prelude operations | Prelude JV | Emissions associated with processing Crux products at the Prelude FLNG facility (following the Crux facility coming online) including:<br>- emissions from power generation, processing facilities, flaring etc.<br>- disposal of reservoir $CO_2$<br>- vessel and helicopter emissions<br>- fugitive emissions | Emissions associated with processing Crux gas at Prelude are within the envelope of the 2.3 Mtpa approved for the Prelude FLNG facility. This estimated gross figure is subject to change and is based on the **highest** predicted emissions (year 2036, respectively) according to available information. Estimated extended field life is simply an extended average of the expected emissions. Expected and extended emissions total deduct the already approved emissions from Prelude under EPBC (2008/4146). | 2.18 | 10 | 75 |
| Transportation to import facility | Crux JV participant/ Third Party | Emissions from a 2780 nautical mile journey to an Asian import facility using typical LNG vessel engine performance. | The sum of emissions from a vessel moving the Crux product to an importing market. The exact market is not known so an average journey was established for the purpose of calculating the associated emissions. The expected and extended timeframes align with the Crux operations cases meaning 20 and 40 years respectively. | 0.16 | 3 | 6 |

| Emission source | Party | Description | Basis of calculation | Estimated Annual Average Emissions ($CO_2$-e Mtpa) | Estimated Total Emissions | |
|---|---|---|---|---|---|---|
| | | | | | Expected Life (20 years) ($CO_2$-e Mt) | Extended Life (40 years) ($CO_2$-e Mt) |
| End-user combustion of the gas | Third-party | Turning the Crux product into the desired marketable product resulting in the end-user producing GHG emissions. Use of the modified marketable product as intended (likely through combustion) resulting in the end-user producing GHG emissions. | This calculation has been informed by representative factors consistent with published practice, including assumptions for:<br>- Lower Heating Value of Natural Gas/LNG = 50.03 g $CO_{2-e}$ / MJ, consistent with emission factors published by the Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry (API, 2009) and associated guidance<br>- Lower Heating Value of Condensate/natural gas liquids = 41.87 g $CO_2$ / MJ, consistent with emission factors published by the Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry (API, 2009) and associated guidance<br>- Regasification emissions are based on typical industry performance using seawater heat exchangers.<br>The expected and extended timeframes align with the Crux operations cases meaning 20 and 40 years respectively. | 8.62 | 172 | 344 |

### Emissions Comparisons

It is useful to put Crux GHG emissions into context in terms of their contribution to national and international GHG emissions inventories. In Australia, the latest published national GHG accounts identify Australia's domestic emissions to be approximately 538 Mtpa (Commonwealth of Australia 2018). There are many publications of the global GHG emissions and projected pathways of impacts under different modelled climate change scenarios. The latest figures from the Global Carbon Project, which releases annual data on GHG emissions, backed up by peer-reviewed publications, identify global fossil fuel $CO_2$ emissions in 2018 to be approximately 37,100 Mtpa (Global Carbon Project 2018). The IEA World Energy Outlook (2019) predicts world energy related $CO_2$ emissions to be 35,589 Mtpa in the Stated Policies Scenario (STEPS) and 15,796 Mtpa in the Sustainable Development Scenario (SDS) by 2040. **Table 8-26** compares the Crux GHG emissions against these amounts.

Table 8-26: Comparisons between the Crux project, Australian and Global GHG emissions (Mtpa $CO_{2-e}$)

| Action | Estimated Emissions | Australian Emissions | Percent of Global Emissions in 2018 | STEPS Global Emissions in 2040 | SDS Global Emissions % in 2040 |
|---|---|---|---|---|---|
| Crux installation | N/A | N/A | N/A | N/A | N/A |
| Crux operations | 0.35 | 0.064% | 0.0009% | 0.0009% | 0.0022% |
| Prelude operations (following the Crux facility coming online) | 2.18 | 0.405% | 0.0059% | 0.0061% | 0.0138% |
| Transportation to import facility | 0.16 | 0.030% | 0.0004% | 0.0004% | 0.0010% |
| End-user combustion of Crux gas | 8.62 | N/A | 0.023% | 0.024% | 0.546% |
| **Totals (excluding Crux installation)** | **11.31** | **0.499%** | **0.0302%** | **0.0314%** | **0.5630%** |

#### 8.4.5.3 Impact and Risk Assessment for Crux Project Scope 1 GHG Emissions

This section assesses the impacts and risks arising from Scope 1 emissions from the Crux project. The impacts and risks are described by study of the possible effects of increasing concentrations of GHG in the atmosphere. This includes carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. These are collectively expressed in terms of an equivalent carbon dioxide ($CO_{2-e}$). The impacts from these emissions is evaluated and management measures are adopted, appropriate to this stage of the project.

The direct emissions from the Crux project are 0.347 Mtpa $CO_{2-e}$ in years 2025 to 2041 and 2.527 Mtpa $CO_{2-e}$ from 2041 onwards. The assessment of impacts is most appropriately completed using the annual average Crux GHG emissions because:

- using the total emissions relies on assuming a life of the facility which is speculative and may underestimate emissions in the expected life case and may overestimate emissions in the extended field life case;
- this method of measurement enables assessment of both the expected and extended field life cases because the annual average of emissions is the same in both cases;
- this method facilitates easier comparison to global targets and international reporting requirements;
- prospective resources within the in-field development area would be developed in such a way to extend the facility life of Crux and Prelude rather than ramp up production volumes; and
- this method of measurement allows for natural and expected variations in emissions throughout the life of the facility.

#### 8.4.5.4 Description of Impacts and Risks

The Intergovernmental Panel on Climate Change (IPCC) published a Special Report, based on the assessment of the available scientific, technical and socio-economic literature relevant to global warming of 1.5°C above pre-industrial levels (IPCC, 2018). According to the IPCC report, human-induced global warming has already caused multiple observed changes in the climate system. Changes include increases in both land and ocean temperatures, as well as more frequent heatwaves in most land regions. There is also high confidence that global warming has resulted in an increase in the frequency and duration of marine heatwaves. There is clear evidence that human-induced global warming has led to an increase in the frequency, intensity and/or amount of heavy precipitation events at the global scale, as well as an increased risk of drought in some regions.

According to Dunlop et al. (2012), the effect climate change may have on marine and terrestrial species, is likely to be highly species-dependent and vary geographically. At a broad-scale, fauna distribution patterns may shift in response to climate change. The most frequently observed and cited ecological responses to climate change include species distributions shifting towards the poles and upwards in elevation and shifts in life-cycle events. Some of the potential taxa-level effects (potential vulnerabilities) are presented in **Table 8-27**.

Climate change may not only change species distribution patterns but also life-history traits, such as migration patterns, reproductive seasonality and sex-ratios (see **Table 7-6**). As an example, a study conducted on Australian migratory birds and migration timing, observed that birds are typically arriving 3.5 days earlier per decade since 1960, with half the species showing significantly earlier arrival (Climate Risk no date). The study was based on the arrival and departure dates for 24 and 14 species, respectively, with the data spanning the past 40 years. In marine turtles, cooler temperatures produce more male hatchlings while warmer temperatures produce more females. Research undertaken into the genetically distinct breeding population of green turtles on the northern and southern Great Barrier Reef has indicated that recent warming has led to an abundance of female turtles being born to the northern breeding population. The results showed turtles originating from warmer northern Great Barrier Reef nesting beaches were extremely female-biased, with female turtles accounting for 99.1% of juvenile, 99.8% of sub-adult, and 86.8% of adult-sized turtles (Jensen et al. 2018). In comparison, turtles originating from the cooler southern Great Barrier Reef nesting beaches showed a more moderate female sex bias, with female turtles accounting for 68% of juvenile, 65% of sub-adult, and 69% of adult-sized turtles (Jensen et al. 2018).

Table 8-27: Potential Effects of Climate Change to Future Vulnerability of Particular Taxa

| Taxa | Potential Vulnerability |
|---|---|
| Mammals | Narrow-ranged endemics susceptible to rapid climate change in situ; changes in competition between grazing macropods in tropical savannas mediated by changes in fire regimes and water availability; herbivores affected by decreasing nutritional quality of foliage as a result of $CO_2$ fertilisation. |
| Birds | Changes in phenology of migration and egg-laying; increased competition of resident species with migratory species due to migratory birds staying longer at breeding grounds; breeding of waterbirds susceptible to reduction in freshwater flows into wetlands; top predators vulnerable to changes in food supply as a result of increased sea temperatures; rising sea levels affecting birds that nest on sandy and muddy shores, saltmarshes, intertidal zones, coastal wetlands and low-lying islands; saltwater intrusion into freshwater wetlands affecting breeding habitat. |
| Reptiles | Warming temperatures may alter sex ratios of species with environmental sex determination (e.g. turtles and crocodiles). Some species may modify their use of microhabitats to cope with warming in situ. |
| Amphibians | Frogs may be the most at-risk terrestrial taxa. Amphibians may experience altered interactions between pathogens, predators and fires. |
| Fish | Freshwater species vulnerable to reduction in water flows and water quality; limited capacity for freshwater species to migrate to new waterways; all species susceptible to flow-on effects of warming on the phytoplankton base of food webs. |
| Invertebrates | Expected to be more responsive than vertebrates due to short generation times, high reproduction rates and sensitivity to climatic variables. |
| Plants | Climate change may impact various functional dynamics of plants due to changes in fires, plant phenology and insect life cycles and specific environmental characteristics. Longer lived plants may be more vulnerable if climate change ‘moves’ suitable establishment sites for seedlings beyond their dispersal distances. Narrow-ranged endemic plants requiring specific conditions will have limited capacity to disperse to sites with similar conditions. |

(adapted from Steffen et al. 2009)

The following paragraphs are a discussion of the possible effects to the Australian environment from climate change in general. As will be explained in the evaluation, while there is a relationship between GHG emissions and climate change, it is not possible to know the exact contribution of Crux emissions (and the emissions from end-user produced emissions) to these possible effects. CSIRO (2018) is forecasting that Australia is projected to experience the following climate changes:

- further increases in sea and air temperatures, with more hot days and marine heatwaves, and fewer cool extremes;
- further sea level rise and ocean acidification; and
- decreases in rainfall across southern Australia with more time in drought, but an increase in intense heavy rainfall throughout Australia.

A summary of the predicted effects to key Australian ecosystems as a result of climate change is presented in **Table 8-28**. Most marine and terrestrial ecosystems are susceptible to climate change; however, the predicted impact is highly variable, both between ecosystems and within individual ecosystems.

Changes in climate, such as altering temperature, rainfall patterns and fire regimes, due to climate change is likely to result in changes in vegetation structure across all terrestrial ecosystems within Australia (Dunlop et al. 2012). Increases in fire regimes will impact Australian ecosystems by altering composition structure, habitat heterogeneity and ecosystem processes, and may assist in the spread of introduced species (which may further alter or increase the incidence of fires). Changes in climate variability, as well as averages, could also be important drivers of altered species interactions (Dunlop et al. 2012).

Table 8-28: Projected Effects of Climate Change on Key Australian Ecosystems

| Selected Component of Environmental Change | Projected Effects |
|---|---|
| *Coral Reefs* | |
| $CO_2$ increases leading to increased ocean acidity | Reduction in ability of calcifying organisms, such as corals, to build and maintain skeletons. |
| Sea surface temperature increases, leading to coral bleaching | If the frequency of bleaching events exceeds the recovery time, reefs will be maintained in an early successional state or be replaced by communities dominated by macroalgae.<br>Warming will increase the susceptibility of corals to diseases.<br>Potential for new reefs to develop at higher latitudes where suitable substrates are available and until light becomes limiting; potential decrease in beta diversity of coral communities as tropical-adapted taxa expand their range to the south, amplified by differential survival of different taxa, |
| Increases in cyclone and storm surge | Increased physical damage to reef structure. |
| *Oceanic Systems (including planktonic systems, fisheries, sea mounts and offshore islands)* | |
| Ocean warming | Many marine organisms are highly sensitive to small changes in average temperature (1–2ºC), leading to effects on growth rates, survival, dispersal, reproduction and susceptibility to disease. Increasing temperatures reduce larval development time, potentially reducing dispersal distances; warm-water assemblages may replace cool-water communities. |
| Changed circulation patterns, including increase in temperature stratification and decrease in mixing depth, and strengthening of East Australian Current | Distribution and productivity of marine ecosystems is heavily influenced by the timing and location of ocean currents; currents transfer the reproductive phase of many organisms, therefore playing an important role in dispersal and maintenance of populations. Climate change may suppress upwelling in some areas and increase it in others, leading to shifts in location and extent of productivity zones. |
| Changes in ocean chemistry | Increasing $CO_2$ in the atmosphere is leading to increased ocean acidity and a parallel decrease in the availability of carbonate ions, which are the building blocks of calcium carbonate skeletons (such as those of many planktonic species and corals. Increased dissolved $CO_2$ may increase productivity. |
| *Estuaries and Coastal Fringe (including benthic, mangrove, saltmarsh, rocky shore, and seagrass communities)* | |
| Sea level rise | Landward movement of some species (particularly mangroves) as inundation provides suitable habitat, changes to upstream freshwater habitats will have flow-on effects to species such as wetland birds. |
| Increase in water temperature | Effects on phytoplankton production will affect secondary production in benthic communities. |
| *Savannas and Grasslands* | |

| **Selected Component of Environmental Change** | **Projected Effects** |
|---|---|
| Elevated $CO_2$ | Shifts in competitive relationships between woody and grass species due to differential responses. |
| Increased rainfall in north and north-west regions | Increased plant growth will lead to higher fuel loads, in turn leading to fires that are more intense, frequent, occur over large areas and occur later in the dry season. Change to ecotonal boundaries between savanna woodlands, grasslands and monsoonal rainforest patches. Changes in rainfall seasonality are likely to be more important than changes in amount. |
| *Tropical Rainforests* | |
| Warming and changes in rainfall patterns | Increased probability of fires penetrating rainforest vegetation resulting in shift from fire-sensitive vegetation to communities dominated by fire-tolerant species. Cool-adapted species forced to higher elevations, altering competitive interactions. |
| Change in length of dry season | Altered patterns of flowering, fruiting and leaf flush will affect resources for animals. |
| Increased intensity of storms/tropical cyclones | Increased physical disturbance to forests, which alters gap dynamics and succession rates; shallow-rooted tall rainforest trees are particularly susceptible to uprooting, breakage and defoliation. |
| Rising atmospheric $CO_2$ | Differential response of different growth forms to enhanced $CO_2$ may alter structure of vegetation. |
| *Temperate Forests* | |
| Potential increases in frequency and intensity of fires | Changes in structure and species composition of communities with obligate seeders may be disadvantaged compared with vegetative resprouters. |
| Warming and changes in rainfall patterns | Potential increases in productivity in areas where rainfall is not limiting; reduced forest cover associated with soil drying projected for some Australian forests. |
| Rising atmospheric $CO_2$ | Overall increase in productivity and vegetation thickening. |
| *Inland Waterways and Wetlands* | |
| Reductions in precipitation, increased frequency and intensity of drought | Reduced river flows and changes in seasonality of flows; reduction of the area available for waterbird breeding. More intense rainfall events will increase flooding, affecting movements of nutrients, pollutants and sediments, riparian vegetation, and erosion. Groundwater dependent ecosystems may be negatively affected. |
| Changes in water quality, including changes in nutrient flows, sediment, oxygen and $CO_2$ concentration | May affect eutrophication levels, incidence of blue-green algal outbreaks; loss of cool-adapted species and increase in populations of warm-adapted species. |
| Sea level rise | Saltwater intrusion into low-lying floodplains, freshwater swamps and groundwater; replacement of existing riparian vegetation by mangroves. |
| Warming of water column; increase in depth of seasonal thermoclines in still water | Changes in abundance of temperature-sensitive species, such as algae and zooplankton; reduction in depth of lowest oxygenated zones in some instances. |
| *Arid and Semi-arid Regions* | |
| Increasing $CO_2$ coupled with drying in some regions | Interaction between $CO_2$ and water supply critical, as 90% of the variance in primary production can be accounted for by annual precipitation. |
| Shifts in seasonality or intensity of rainfall events | Any enhanced runoff redistribution will intensify vegetation patterning and erosion cell mosaic structure in degraded areas. Changes in rainfall variability and amount will also affect fire frequency. Dryland salinity could be affected by changes in the timing and intensity of rainfall. |

| Selected Component of Environmental Change | Projected Effects |
|---|---|
| Warming and drying, leading to increased frequency and intensity of fires | Reduction in patches of fire-sensitive mulga in spinifex grasslands potentially leading to landscape-wide dominance of spinifex. |
| *Alpine/Montane Areas* | |
| Reduction in snow cover depth and duration | Potential loss of species dependent on adequate snow cover for hibernation and protection from predators; increased establishment of plant species at higher elevations as snowpack is reduced. |

(adapted from Steffen et al. 2009)

#### 8.4.5.5 Evaluation of Impacts and Risks

This section evaluates the impacts of total Scope 1 GHG emissions. The Crux project does not have any Scope 2 emissions. The broader impacts from GHG emissions are typically considered by the international community at an ecosphere level, most frequently in terms of an increase in global temperatures. **Table 8-28** identified the climate projections on the Australian environment from the increase in global temperatures.

Climate projections depend upon emission/concentration/radiative forcing scenarios, which are based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty (UNITAR 2015).

Climate projections are distinct from climate predictions. Climate predictions are estimates of future natural conditions, while climate projections are estimates of future climates under the assumptions of future human related activities such as socio-economic and technical developments. Making a prediction of GHG emission impacts at the ecosphere level is an inherently complex exercise because of the influence of variables such as surface pressure, wind, temperature, humidity and rainfall within multiple ecosystems. The listed items are all interdependent variables that would have to be taken into consideration in determining a contribution to global temperature increase. For each variable a series of generalising assumptions would be required to be able to make a sensible calculation of the impacts. Considering the complex and dynamic natural processes within the ecosphere, there is substantial uncertainty in determining a specific increase in global temperature due to the Crux project and its emissions.

As such, it is equally speculative to suggest an isolated climate event, or series of climate events, that lead to a change to any environmental value or sensitivity within Australia (including Matters of National Environmental Significance (MNES), are solely attributable to a specific increase in global temperature. As such, it is not possible to isolate the influence of Crux emissions to any conclusive impact on the Australian environment. This results in a lack of full scientific certainty about the impacts of Crux GHG emissions.

**Ecologically Sustainable Development – Precautionary Principle**

To be consistent with the precautionary principle, one of the guiding principles of Ecologically Sustainable Development (ESD) is that the lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation if there is also a threat of serious or irreversible environmental degradation from the action.

Considering the national and international comparisons in **Table 8-26**, Scope 1 emissions from the Crux project are a small portion of emission inventories, even in the

SDS. This suggests a similarly small contribution to global temperature increases even though there is no calculable direct relationship.

However, the reasons previously given for being unable to quantify any increase in emissions contribution to an increase in global temperature also hold for these comparisons. Nevertheless, the numbers presented are extremely small, meaning that even if these estimates have orders of magnitude variance, it is still reasonable to conclude that, holding all other factors constant, the Crux projects Scope 1 emissions contribution to any increase in global temperatures will be small.

Whilst Scope 1 GHG emissions from Crux contribute a small amount to Australian and global GHG emissions this fact alone does not make their impacts inherently acceptable. The relatively small percentage of global emissions should not be used to understate the seriousness of the threat of environmental degradation from climate change. Rather it clarifies the source of the threat being from global emissions quantities rather than from emissions from the Crux project. The threat of serious environmental degradation from climate change comes from an increasing global population demanding more energy to maintain and improve global living standards. Whilst the Crux project accounts for a tiny percentage of this demand it does not create an isolated instance of a threat of serious or irreversible environmental degradation.

Whether climate change is irreversible is even more scientifically uncertain than predicting impacts from Scope 1 & 2 GHG emissions from Crux for the same reasons that made that prediction speculative. The environmental influences of variables such as surface pressures, wind, temperature, humidity, and rainfall are added to the variables of human adaption measures to a lower carbon economy. This is demonstrated by the difference between the Stated Policy Scenario (STEPS) and the Sustainable Development Scenario (SDS) considered by IEA.

Shell considers that the Commonwealth Government through the Safeguard Mechanism in the NGER Act enforces a precautionary approach by requiring prevention, abatement, and offset of Scope 1 and Scope 2 GHG emissions from the Crux project. This results in a legislative requirement that addresses uncertainty in the quantification of any identifiable change in the environment because if emissions exceed the approved baseline, offsets (in the form of Australian Carbon Credit Units (ACCUs) are legally mandated.

**Social Impact**

The Crux project will be in the offshore waters of Western Australia. Depending on the observation point and weather conditions the Crux platform will be visible at a radius of approximately 20km. The project is approximately 200km from the Australian mainland and can be considered a remote location. The project will have no visual disturbance other than to passing ships or fishers. There are shoals proximate to the proposed facility location however given their remoteness they have no quantifiable amenity use. Environmental impacts and risks to these shoals and other marine users have been considered elsewhere in this OPP. The physical location of the Crux project is an ideal place for an energy development because it results in negligible social impacts, unlike some other onshore development opportunities for gas, renewables, or higher emission fuels.

#### 8.4.5.6 Management and Mitigation of Impacts from Scope 1 Emissions

Shell understands and recognises the importance of managing its GHG emissions to be consistent with the principles of ESD. This has been demonstrated in the GHG emissions abatement already achieved during the design phase of the project through the implementation of the GHGEMP. In addition, the following commitments will be reflected and updated in future activity-specific Environment Plan submissions, and in each mandatory 5-year revision:

- flaring during operations will be optimized to enable the safe and economically efficient operation of the facility;
- selection of gas turbine generators during design process considers energy efficient (i.e. low emission) equipment, in alignment with the selected concept; and
- TEG off-gas will not be vented but sent to the flare for combustion if the flare is ignited.

The level of Crux emissions means the project is subject to internal Shell guidance of the GHGEMP (which is subordinate to the HSSE & SP Control Framework). The Control Framework requires the project to implement and maintain a GHGEMP.

The purpose of the GHGEMP and its associated processes is to record the identification, evaluation, and implementation of GHG emissions abatement measures. It provides a centralized means of monitoring the projects GHG performance and the continual maintenance of impact to within the defined levels of performance.

The purpose of requiring GHGEMPs is to embed GHG considerations into normal decision-making and business/project evaluation while employing a common language for GHG-risk evaluation. It is through project design decisions that the Crux project can commit to enabling technologies that are practical, cost-effective and with outcomes to minimise $CO_2$ emissions through design and implementation.

The Crux project will have two GHGEMP's; one for the Prelude facility[16] and one for the Crux facility. Each GHGEMP will be kept up to date through an annual abatement workshop. The GHGEMP and workshop have the following features which enable GHG emissions to be maintained below an acceptable level of impact:

- GHG emissions will be managed to ensure compliance with Commonwealth legislation for the management of GHG emissions;
- An annual review of GHG abatement opportunities during OPERATE phase to reduce GHG emissions;
- All feasible GHG abatement opportunities during OPERATE phase will be considered;
- An economic analysis will be conducted on all GHG abatement opportunities to determine if abatement options will reduce this impact to As Low As Reasonably Practicable (ALARP).

**Conclusion: Crux Project GHG Emissions Impact Assessment**

Increasing levels of GHG in the atmosphere is one contributing factor to the warming of the climate system. There is a lack of full scientific certainty about the effects of increased emissions, but they are understood to be non-linear. The evaluation considered that GHG emissions are among the causes of climate change, particularly if unmitigated.

It is argued that calculating the Crux project's specific contribution to climate change would be speculative and would likely provide unreliable, inaccurate, and uncertain results. As evidence for this assertion, the evaluation has shown the substantial uncertainty in making an evaluation stems from two equally complex and dynamic sets of interdependent variables. The first is from predicting the contribution of Crux GHG emissions to a specific increase in global temperatures, and the second comes from

[16] The Crux JV is unable to make commitments to GHG abatement on behalf of the Prelude JV.

making a prediction of impacts on the Australian environment from the increase in global temperatures.

In conclusion, the environmental impacts and risks arising from Scope 1 & 2 GHG emissions from the Crux project will be managed to an acceptable level because:

- The development concept with the lowest technical and economic GHG emissions profile has been selected.
- The project utilises existing infrastructure (Prelude) to minimise overall emissions.
- All economically viable opportunities to further reduce GHG emissions have been adopted during the design phase.
- It is speculative to assess the impacts of the Crux project's GHG emissions noting that, on a qualitative basis, the impacts from Crux GHG emissions are unlikely to be a substantial cause of an increase in global temperature and Crux GHG emissions are also unlikely to be a substantial cause of climate change impacts to the Australian environment.
- Uncertainty in the assessment of impacts will be managed through the ongoing GHGEMP processes and the legislative arrangements that apply to the Crux project, in particular, the Safeguard Mechanism under the NGER Act.
- The impacts of Crux GHG emissions are consistent with the principles of ESD in that proceeding with the project in this remote location does not displace other users or uses, or future users or uses, from the location.
- The impacts have been assessed and will be mitigated, abated, and (where legally required) offset.
- The project will be carried out on titles granted by the Federal Government.

### 8.4.5.7 Risk and Impact Summary Table

Table 8-29: Crux GHG Emissions Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Planned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Magnitude | Sensitivity | Residual Impact |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from GHG emissions arising from the Crux project, including contribution to the incremental build-up of GHG in the atmosphere | X | X | X | X | Minor effect | Low | Minor |
| **Evaluation – Unplanned Risks** | | | | | | | |
| **Project Component/ Activity** | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Significance** | **Likelihood** | **Residual Risk** |
| Unplanned consequences from venting of hydrocarbon gas. | X | X | X | X | Slight | Remote | Negligible |
| ***Key Management Controls*** | | | | | | | |
| All drilling rigs, vessels and Crux platform (as appropriate to vessel class) will comply with MARPOL Annex VI (Prevention of air pollution from ships), the *Navigation Act 2012*, the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and subsequent Marine Orders. which requires vessels to have a valid International Air Pollution Prevention Certificate (for vessels > 400 tonnage) and use of low sulphur fuel, when possible.<br>Flaring during operations is optimised to enable the safe and economically efficient operation of the facility.<br>Selection of gas turbine generators during design process considers energy efficient (i.e. low emission) equipment, in alignment with the selected concept.<br>TEG off gas will not be vented but sent to the flare for combustion if the flare is ignited.<br>During operations of the Crux facility, regular reviews of GHG opportunities will be reviewed and adopted where appropriate. This will be implemented through a GHG Energy Management Plan (GHGEMP), that will be kept up to date through an annual abatement workshop. | | | | | | | |

### 8.4.5.8 Acceptability of Impacts and Risks

The methods by which this acceptable level was determined, along with a justification as to why it is acceptable, are discussed in **Section 5.7**.

**Principles of Ecologically Sustainable Development (ESD)**

The risks and impacts from GHG emissions from the Crux project are consistent with the principles of ESD based on:

- the precautionary principle has been applied, and mitigation measures have been adopted in the absence of full scientific certainty;
- global policies and actions related to GHG emissions have been considered and Australian legislation supports these policies and will be complied with; and
- the Crux project has been subject to public comment and regulatory scrutiny which ensures the broadest community of people have been involved on management of issues that affect them.

**Matters of National Environmental Significance**

There is no clear and convincing evidence that GHG emissions from the Scope 1 GHG emissions from Crux will result in significant impacts to threatened or migratory species. The impacts and risks from the GHG emissions aspect of the Crux project on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Table 7-1**.

**Internal and External Context**

The legislative frameworks for managing impacts of Crux GHG emissions are well-developed and comprehensive because they cover prevention, abatement, and offset of emissions in a structured and predictable way.

Under the Commonwealth government's framework for management of Scope 1 and 2 emissions in Australia Shell reports as a corporate group under the NGER Act and as the entity with "operational control" of the Prelude FLNG facility, this includes emissions from Prelude.

Crux emissions will be incorporated into the total emissions reporting by Shell, once the project becomes operational. Shell will comply with the contemporary requirements as defined under the NGER Act and associated Safeguard Mechanism (including any future amendments), as the project progresses.  In summary this will most likely require Shell to:

- complete and submit annual NGER reports during the operations stage of the Project for the Kyoto Protocol listed (or applicable post-Kyoto agreement at the time of operations) GHG emissions on a $CO_2$ equivalency basis for each facility (as defined in Section 9 of the NGER Act and National Greenhouse and Energy Reporting Regulations 2008) by fuel type, and the relevant requirements of the National Greenhouse and Energy Reporting (Safeguard Mechanism) Rule 2015;
- ensure a Safeguard Mechanism baseline is set for the Crux facility.  Under the current Safeguard Rule this is expected to be determined as a new facility 'benchmark' baseline, defined by reference to best-practice emissions intensities for equivalent facility types; and
- if the Safeguard Mechanism baseline for the project is exceeded, follow requirements outlined under the safeguard mechanism.  This may require Shell to purchase and surrender Australian Carbon Credit Units.

Regarding the NGER Act, the Safeguard Mechanism baseline could be used as a proxy for what the Australian Government has deemed to be an acceptable level of emissions from a given project In addition, oversight is provided by the Clean Energy Regulator audit processes, and there are reasonable penalties associated with exceedances. This creates an incentive for Shell to keep emissions within the established baseline.

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and corporate requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from GHG emissions determined the residual impact and risk ratings were minor and negligible, respectively (**Table 8-29**). Shell considers residual impacts and risks of minor and negligible, respectively, to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to the GHG emissions aspect of the Crux project. Based on the points discussed above, Shell considers the impacts and risks from GHG emissions from the Crux project to be of an acceptable level. The acceptable level of impact for the receptors that may be affected by GHG emissions from the Crux project is summarised in **Table 8-30**.

Table 8-30: Acceptable Levels of Impacts and Risks from GHG Emissions

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| All | Australian environment | No significant impacts to the Australian environment attributable to the Crux project. | Yes. Impacts to the Australian environment are concluded to be low although with a low level of certainty. In the absence of certainty, the Australian government applies a precautionary approach through the NGER Act. Emissions of less than 0.5 Mt in a single year are less than the total emissions from 84% of Australian corporations reporting under the NGER Act. In addition, GHG emissions attributable to the Crux project are not likely to have a significant impact on MNES. In combination with Shell's own GHG abatement commitments the impacts are of an acceptable level. |

#### 8.4.5.9 Environmental Performance Outcomes

GHG emissions associated with the project will be reported consistent with Shell's HSSE & SP Control Framework as well as Commonwealth and State regulations for the management of GHG emissions for the life of the project. Based on current knowledge and assumptions, the environmental performance outcomes of the Crux project are:

- Emissions at the Crux facility will not exceed 0.5 Mt $CO_{2\text{-}e}$ in any single operating year.
- Emissions at the Crux facility will not exceed an average of 0.4 Mtpa $CO_{2\text{-}e}$ over a 5-year period.
- Emissions at the Crux facility will comply with the Australian government safeguard mechanism baseline.

The difference between the predicted scope 1 emissions from Crux (0.35 Mtpa $CO_{2\text{-}e}$) and these quantitative performance outcomes is to make allowance for process uncertainties over the life of the project. This also explains the single year and 5-year performance limits.

#### 8.4.5.10 Impact and Risk Assessment for End User (Scope 3) GHG Emissions

End-user GHG emissions come from the conversion of chemical energy in gas to thermal energy, and, in some cases, further to mechanical energy, and finally electrical energy from the combustion of gas. The fate of gas from the Crux project is most likely combustion by end users. Whilst Shell does not control end-user impacts, Shell attempts here to show how these impacts could be addressed, within the context of playing a role in the global societal ambition to decarbonise the global economy and the atmosphere. Therefore, this section undertakes an impact assessment of end-user emissions from the use of gas as energy.

It includes discussion about the international legal and policy framework for emissions management and the Shell Group approach to addressing end-user GHG emissions. There follows an evaluation of impacts from end-user GHG emissions and how to meet the energy demands of a growing population while at the same time attempting to play a role in society's common goal of addressing climate change. The section concludes with a demonstration about how end-user emissions might be managed to an acceptable level, given that the Shell does not control these emissions.

#### 8.4.5.11 Description of Impacts and Risks

This description of impacts from end-user GHG emissions build on the previously provided information in **Section 8.4.5.4**. The use of gas to create energy occurs daily by millions of businesses and billions of people in heating and powering their homes. Regardless of where end-user emissions occur the effects of combustion of the Crux gas occur at a global level. Given the uncertainty of the scale, timing, and location of any climate impact (or the Crux proportion) it is reasonable to focus more on the emissions than the impacts in this assessment. Because end-user emissions could occur anywhere, they are most appropriately considered at a global level. This description uses relevant information from the United Nations (UN), the IEA, and International Standards Organisation (ISO) to put the end-user's emissions in the context of sustainable development (where sustainable development is a proxy for acceptable levels of impact).

The United Nations has set 17 sustainable development goals. Pertinent to this description of impacts and risks, the UN Goals include the provision of clean and affordable energy alongside other gas/energy related goals about climate action, no poverty, and decent work and economic growth. The complementary framing of these goals is echoed in the IEA World Energy Model which similarly has Sustainable Development Goals (SDG). The SDS previously mentioned outlines a major transformation of the global energy system, showing how the world can change course to deliver on the three main energy-related SDGs simultaneously.

Natural gas plays a role in the SDS, although the extent varies by country, sector, and timeframe. In developed economies, in the near term, gas contributes to security of electricity supply by balancing variable renewables and meeting peaks in demand. In developing economies gas plays a more pronounced role.

The SDS has recently been extended to 2050 and sets out what would be needed to deliver against the three SDGs related to energy: to achieve universal access to energy (SDG 7), to reduce the severe health impacts of air pollution (part of SDG 3) and to tackle climate change (SDG 13). The SDS is aligned with the Paris Agreement and projects global emissions will need to fall to less than 10 gigatons per year by 2050, and net zero by 2070. The World Energy Model and the SDS are useful to consider in detail because they include projections about the role of gas in delivering the SDGs. This detail is provided in three areas; investment, energy demand, and emissions profile.

### Investment

The World Energy Outlook 2019 identifies the need for continuing investment in gas fields in the SDS. It notes that these investments are fully and clearly integrated into global decarbonisation and resource development strategies. Overall investment in fossil fuels diminishes in the SDS. It is the proportionate changes in coal, oil, gas, and biofuels that are particularly illustrative of the ongoing role of gas in the scenario.

**Figure 8-6** shows the investment in these fuels in the SDS up to 2050 (IEA). It shows that investment in coal, oil, and gas need to decrease by 80%, 52%, and 20% respectively. Conversely biofuel investments increase 3-fold. This is reflective of the emissions intensity of these fuel sources. It confirms the ongoing role of gas in sustainable development through to 2050 and its relative importance in comparison to other fossil fuels.

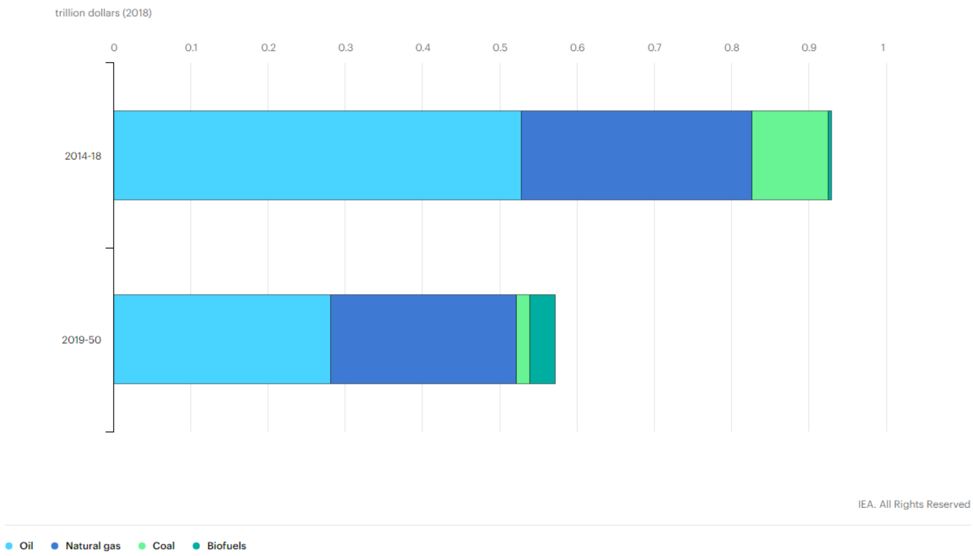



Figure 8-6: Investment in fossil fuels in the Sustainable Development Scenario

### Energy Demand

Energy demand is an important consideration in understanding the impacts from end-user emissions because it can illustrate future trends for types of fuel sources that have different emissions profiles. Under the STEPS energy demand rises by 1.3% each year to 2040. The US Energy Information Administration projects a near 50% increase in world energy usage by 2050, led by growth in Asia. **Figure 8-7** shows the LNG imports in emerging Asian economies and shows that demand for LNG in Asian markets increases even in the SDS. This is because of the allowances for increasing demand in developing economies and decreasing demand in advanced economies.

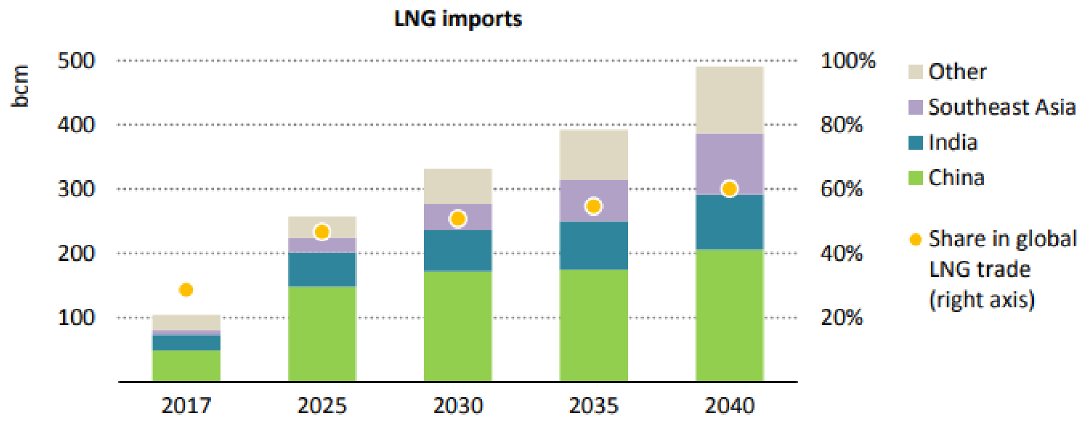



Figure 8-7: Asian LNG demand in the Sustainable Development Scenario (World Energy Outlook 2019)

**Figure 8-8** shows the change in gas demand between the STEPS and SDS. It shows that there are different expectations between developing and advanced economies and that advanced economies will consume much less gas than today in the SDS. These changes in gas demand are significant for the evaluation of impacts because it shows the largest reduction in developing economies' demand needs to occur in the industry and power sectors. This point is reinforced for the power sector by the data in **Figure 8-9** which shows the difference in air pollution by sector between 2015, the STEPS, and SDS.

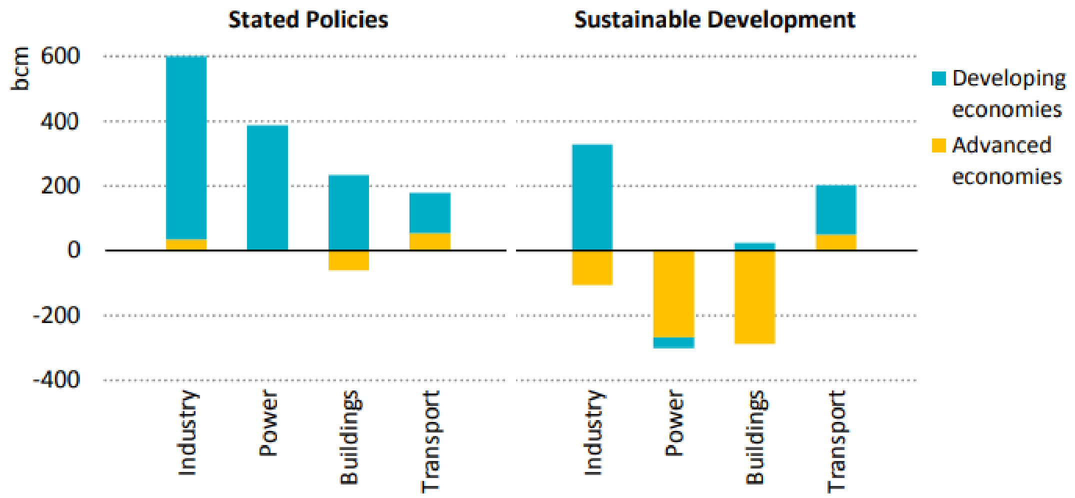



Figure 8-8: Change in gas demand in advanced and developing economies (World Energy Outlook 2019)

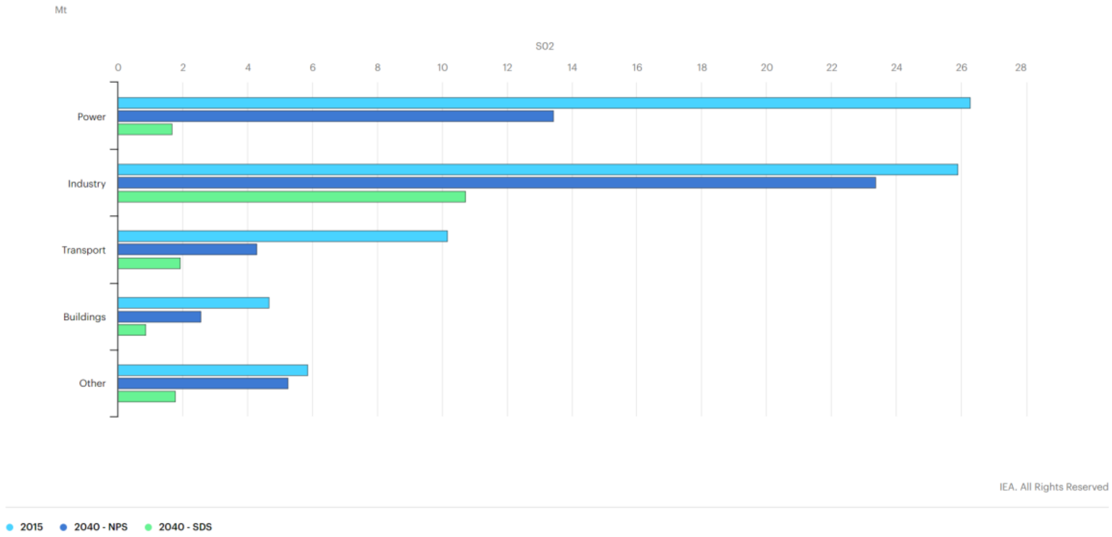



Figure 8-9: Change in air pollution by sector (World Energy Model - IEA 2019)

**End-user Emissions Projections**

In the SDS, energy-related $CO_2$ emissions peak in 2020. To achieve the reduction in emissions required to meet the SDS there needs to be a series of changes in the sources of emissions. **Figure 8-10** shows the change in emission sources required between the STEPS and SDS. Pertinent to the end-user impacts from Crux gas is the 8% change attributable to fuel switching. Since 2010, coal-to-gas switching has already prevented over 500 million tons of emissions (World Energy Outlook 2019).

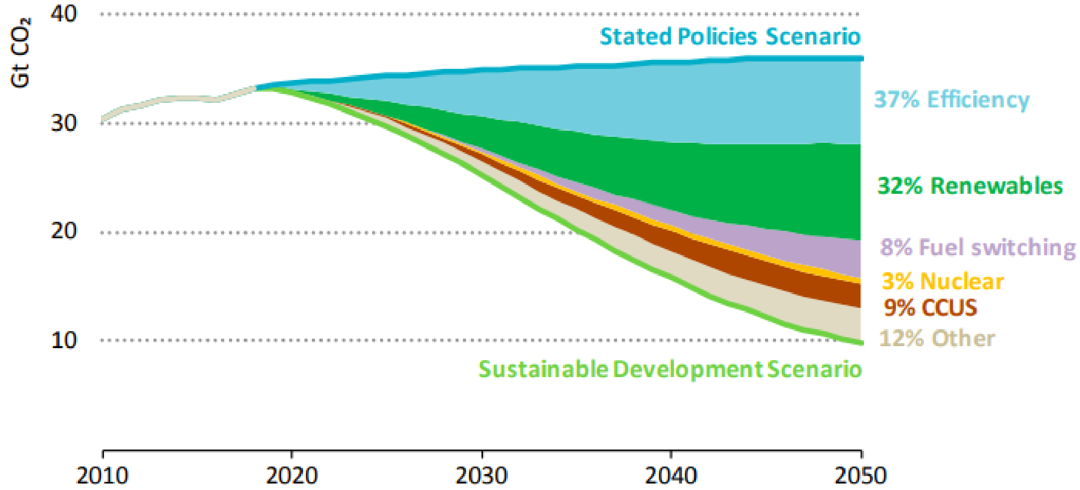



Figure 8-10: Energy-related CO2 emissions and reductions by source in the SDS

Fuel switching in industrial applications contributes to 28% of $CO_2$ emissions reductions needed to meet the SDS (**Figure 8-11**). The speed and rate of coal-to-gas switching is partly driven by carbon pricing policies within user markets and through government mandates. In Europe, rising carbon prices mean gas-fired power plants are competitive with coal whereas Asian markets require a much lower prices for gas to be competitive with coal.

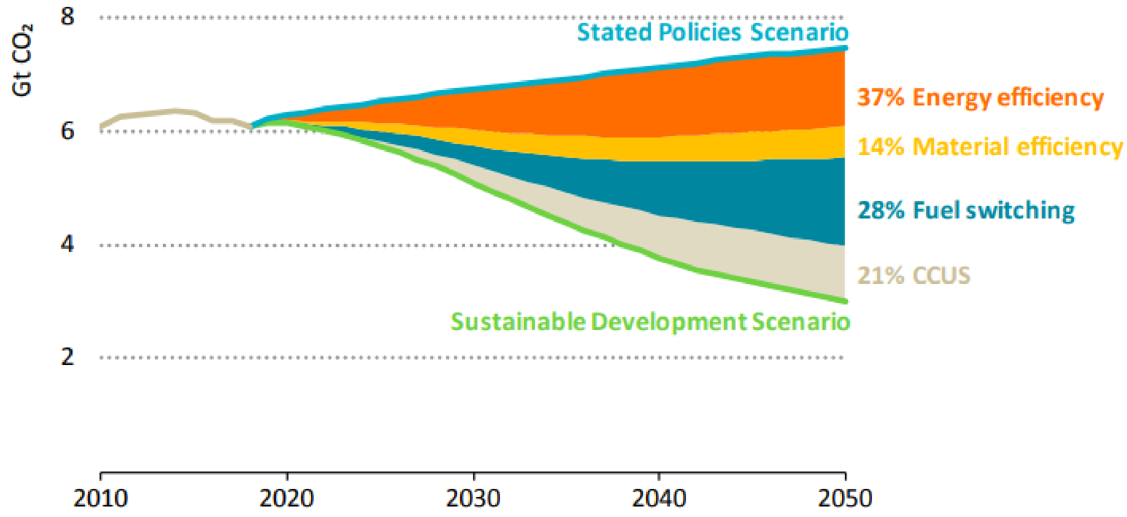



Figure 8-11: Savings in energy-related $CO_2$ emissions in industry by measure and scenario

Gas demand in China is lower in the SDS, but still helps to displace coal demand in both power and industry, while in India gas demand is even higher than in the Stated Policies Scenario as gas replaces coal as a baseload source of electricity generation (World Energy Outlook 2019). The significance of this change in China and the Rest of Asia is shown in **Figure 8-12**.

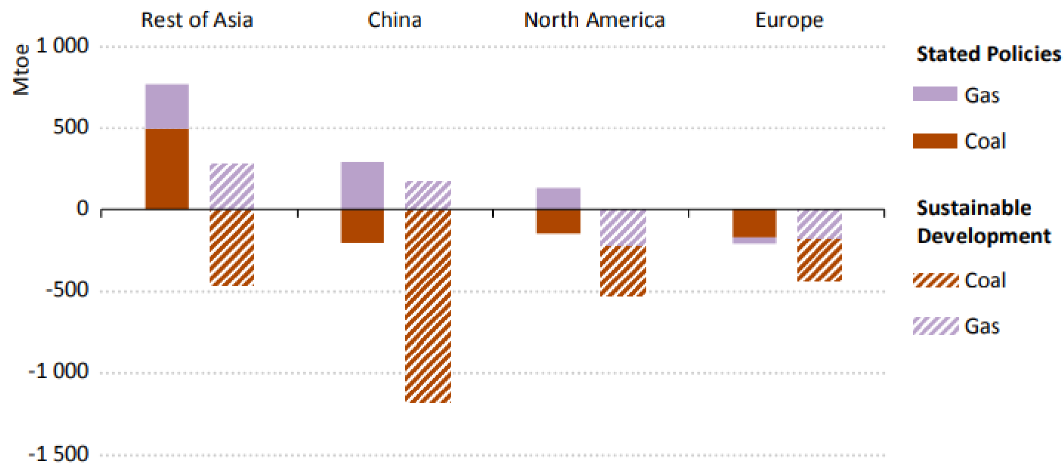



Figure 8-12: Change in gas and coal demand by scenario, 2018-2040

The preceding paragraphs establish that there is and will continue to be a critical role for gas, even in the SDS. A quantification of total end-user GHG emissions for the Crux project has already been derived consistent with the Corporate Value Chain (Scope 3) Accounting and Reporting Standard (WRI/WBCSD, 2011; referred to as the 'GHG Protocol Scope 3 Standard') and the associated Technical Guidance for Calculating Scope 3 Emissions (WRI/WBCSD, 2013). The methodology follows the International Standards Organisation (ISO) 14040:2006 Life Cycle Assessment principles and framework (ISO 2006). End-user GHG emissions, assuming a linear demand and no reduction, mitigation or offset, could be up to 8.62 Mtpa $CO_{2-e}$.

#### 8.4.5.12 Evaluation of Impacts and Risks

This section evaluates Scope 3 emissions in relation to their contribution to climate change. Section 6.2.1 details the possible effects of GHG emissions. To determine the contribution of Scope 3 emissions to climate change effects would require consideration of a range of interdependent variables only some of which may be reasonably predicted. Variables that cannot be reliably estimated are:

- possible end-user modifications to the Crux product;
- the actual combustion efficiencies of the end user;
- the effectiveness of emissions reduction policies in the emitting jurisdiction; and
- implications of current and future supply or demand disruption from unforeseen global events such as pandemics, conflicts, or geopolitical changes.

Three variables that can be considered further are:

- knowledge of whether the Crux gas replaces gas from other sources;
- an understanding of the specific emissions control frameworks in the importing jurisdictions which may be reasonably foreseeable as an Asian market, and probably Japan, South Korea and China; and
- knowledge of whether the gas is used as a substitute for other energy sources such as coal or oil which would have a net decrease on emissions and likely improvement in air quality in those impacted airsheds.

These latter two variables are considered further below because they provide useful context about the management of end-user GHG emissions. However, information on all the variables listed is required to determine a contribution of end-user emissions to climate change. Gathering the information necessary to properly account for each variable would be speculative and the difficulties in making such a prediction have previously been demonstrated.  Therefore, it is not possible to provide a definitive evaluation of end-user impacts.

**International GHG Emissions Control Frameworks**

In respect of end-user actions occurring overseas, two international environmental legal principles are of relevance; the principle of common but differentiated responsibilities and the principle of sovereignty and responsibility. It is upon these legal principles that the UNFCCC global carbon accounting framework has been established, which places the responsibility for mitigating end-user emissions on the emitting country. This is important because the end-user impacts can easily be double counted if countries didn’t have such an arrangement.

Double counting needs to be avoided in order to preserve the environmental integrity of the mitigation mechanisms generating emission reductions and therefore of the mitigation regime under which they operate. Emission reductions being counted more than once implies an overestimation of mitigation results, so failing to prevent double counting could hinder the achievement of internationally agreed mitigation objectives and undermine the credibility of the climate regime (Climate Focus 2016). Double counting risks are dealt with directly in the Paris Agreement through accounting for NDCs, voluntary cooperation, and transparency of transferred mitigation actions.

*Common but Differentiated Responsibilities*

In respect of Crux end user GHG emissions, the international environmental legal principle of common but differentiated responsibilities provides a basis for the international legal framework. The principle holds that all states (i.e. countries rather than businesses) are responsible for addressing global environmental degradation yet are not equally responsible. The principle balances, on the one hand, the need for all countries to take responsibility for global environmental problems and, on the other hand, the need to recognize the wide differences in levels of economic development between countries.

Australia, for example, has a more ambitious target than developing countries precisely because of this principle.

In the context of end-user impacts it is incumbent on the Government in each country to consider global environmental issues and balance those with the economic opportunities associated with the development of that country's natural resources. In respect of Commonwealth resources, the Commonwealth Government balances the sustainable development of its natural resources through a titles release process administered by the National Offshore Petroleum Title Administrator. The grant of an exploration title is the first of many approvals required to undertake a project. Pursuant to successful exploration the Federal Government must also issue a production licence and accept a Field Development Plan (FDP) for the project to proceed. In relation to the Crux project, Shell has been granted titles to explore for hydrocarbons and is currently seeking grant of a production license and acceptance of an FDP.

In the Commonwealth Government's consideration of its international responsibilities, in accordance with the principle of common but differentiated responsibilities, the primary tool to constrain GHG emissions is, as noted in Section 6.1.2.2, the Safeguard Mechanism under the NGER Act. The NGER Act sets out legal obligations in relation to both Scope 1 and Scope 2 emissions, which occur in Australia, but contains no obligation to calculate to report upon end-user emissions, nor an obligation to account for or offset those emissions under the Safeguard Mechanism.

*Sovereignty and Responsibility*

The principle of sovereignty and responsibility holds that individual countries alone have the competence to develop policies and laws in respect of the natural resources and the environment of their territories. This legal structure is incongruent to the environmental structure that consists of a biosphere of interdependent ecosystems. The use by one country of natural resources within its territory will invariably have consequences for the environment in another country. This is evident where rivers run through multiple countries, animal populations migrate, and GHG emissions occur. Ecological interdependence poses a fundamental challenge for international law and demonstrates why international cooperation and international environmental standards are indispensable. The Kyoto Protocol and Paris Agreement are two of the most important examples of international cooperation on global environmental targets and mechanisms to address climate change. Under these agreements the nations responsible for end-user emissions would be expected to account for and address the emissions from transport and combustion of fuels in their own countries.

**End-user Energy Demand and GHG Emissions in Target Markets**

As established in the description of impacts in section 6.3.2.2, analysis of energy demand in export markets can provide important insights into the role of gas in those markets. Coal-to-gas switching in the power sector was identified as the largest likely contributor to net emissions reduction. Therefore, this part of the evaluation focuses on coal-to-gas switching in the target markets for Crux gas.

Given the demand for gas in Asia, and the location of the project, it is most likely that the Crux end-users will be in this region. Crux products will become available to purchase after 2025. Whilst gas demand is well understood for most countries beyond this timeframe, not all gas products are the same. Gas markets are highly variable based on supply levels and quality. So, country specific demand for Crux gas is less predictable and calculating the exact distribution of Crux gas to specific countries is highly speculative. Therefore, this analysis focuses on available emissions data and announced policies from publicly available sources.

Whilst the exact location of markets for the gas are not yet known, and quantities are not yet committed to any specific market, it is reasonably foreseeable that a large proportion of Crux gas will be imported by China, South Korea, and Japan because:

- these countries account for 5.7%, 4.7%, and 11.9% of global LNG demand respectively – a total of 22.3% - based on 2014 statistics (CIA World Factbook 2017); and
- cargos from other Australian LNG projects have mostly been supplied to these countries.

**Table 8-31** shows the proportion of Crux gas in three probable market countries in two circumstances; (1) if the gas were evenly distributed across only these three countries, and (2) if the entire inventory of Crux gas reserves were supplies to a single country. Crux products may go to end-users in other countries than these three, so these scenarios likely overestimate their contributions within the three countries. The mean average of Crux gas supply over 20 years has been used to permit comparison to an annualised demand. This is based on the estimated gas reserves at Crux being 2 Trillion Cubic Feet (TCF) of gas.

Table 8-31: Percentage demand for Crux gas by probable import market.

| Probable Import Market | Annual Gas Demand (Billion Cubic Metres) | Demand Met by Crux Gas (Even Distribution) | Demand Met by Crux Gas (Sole End-user) |
|---|---|---|---|
| Japan | 125 | 0.7% | 2.2% |
| China | 60 | 1.5% | 4.7% |
| South Korea | 49 | 1.9% | 5.7% |

As previously established, the probable target markets for Crux gas are Japan, South Korea, and China. The subsequent discussion below provides a summary of these countries' positions, including the NDCs made under the Paris Agreement and the current status of their emissions policies. For the figures, BAU means Business as Usual and LULUCF means Land use, land-use change, and forestry.

*Japan*

Japan's power generation mix is largely dominated by gas, with coal retaining a significant share despite new coal capacity cancellations. Figure 8-13 shows the growth in gas and coal demand post the Fukushima incident.

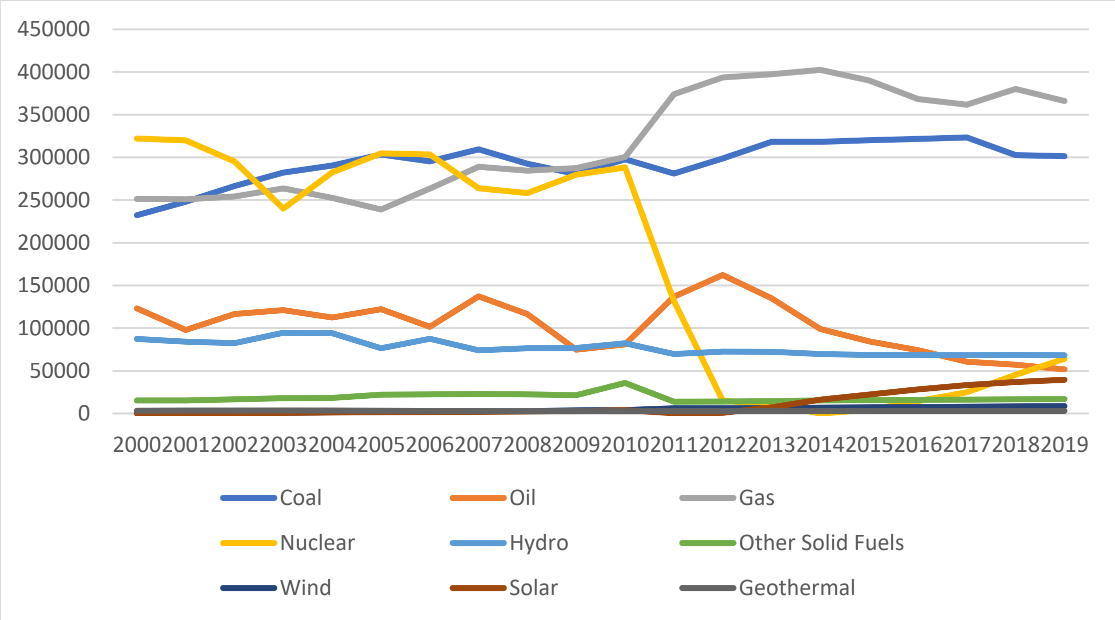



Figure 8-13: Electricity output (in GWh) in Japan (Woodmac 2019)

Post Fukushima, the nuclear power gap was filled in by gas and coal, with gas taking the lead as the dominant fuel in the power sector. Coal capacity was predicted to grow significantly, but has now slowed, with 6.6 GW coal capacity cancelled due to pressure from environmental groups. Assuming this 6.6 GW capacity was operated at 80% plant load factor, if this is now replaced by gas, it could lead to an estimated annual reduction of 18.5 million tonnes of $CO_2$ from power generation alone.

Despite the growth of renewables, the gap left by nuclear and coal will need a significant share of gas to ensure power sector demand is met. Further, the NDC emissions reduction target of Japan would require additional measures and potential coal-to-gas switching to keep the emissions in check. A summary of the Paris Agreement main pledges and targets of Japan are provided in **Figure 8-14**. Japan's long-term emissions are on a downward trajectory but are not in line with its NDC commitment (**Figure 8-15**). Japan would need a significant shift in its energy mix to be able to meet its NDC target of reducing emissions by 26% below 2013 levels by 2030. The current business as usual emissions for 2030 are expected to fall short of the expected reduction committed in the NDC target. In the absence of planned nuclear restarts, despite growth of renewables, increased share of gas and further reduction of coal will be key to achieving their NDC target.

| JAPAN | Main pledges and targets | Climate Action Tracker |
|---|---|---|
| PARIS AGREEMENT | Ratified | Yes |
| | 2030 unconditional target(s) | 26% below 2013 by 2030<br>[15% below 1990 by 2030 excl. LULUCF]<br>[17% below 2010 by 2030 excl. LULUCF] |
| | Coverage | Economy-wide, incl. LULUCF and overseas credits for 2030 |

Figure 8-14: Paris Agreement Main Pledges and Targets - Japan

Source: climateactiontracker.org

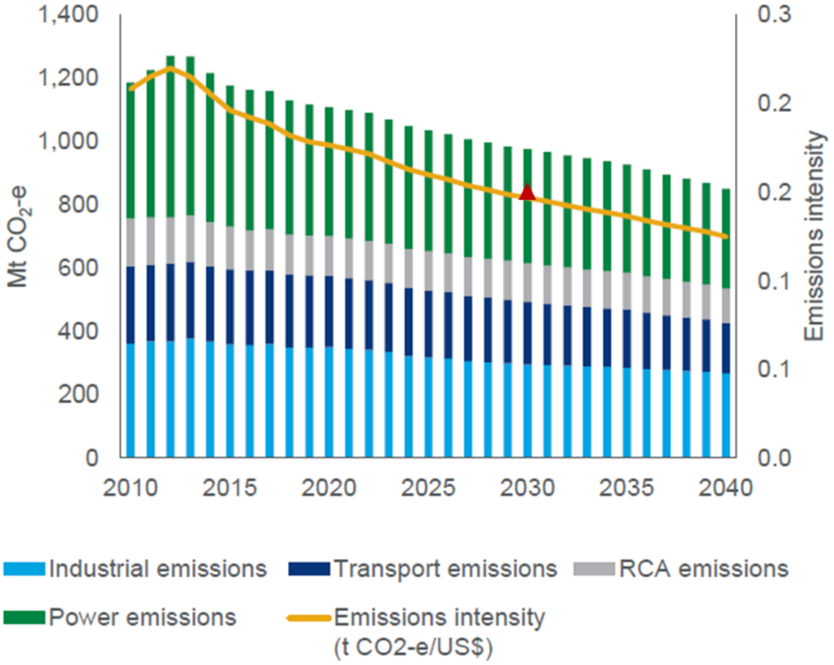



Figure 8-15: Energy related emissions by intensity and sector (Woodmac 2019)

*South Korea*

Historically, the power sector has been coal and nuclear dominated in Korea; and it was also the highest $CO_2$ emitter in the South Korean economy until 2017-18. The power sector has also been the biggest consumer of gas in South Korea; with substantial room to grow if coal consumption and consequent emissions are to be reduced. Renewables targets, although aspirational (58.5 GW by 2030), will still struggle near term to plug the gap left by reduced coal and nuclear use in power. There is a significant opportunity for renewable energy and gas partnership to plug the gap.

In 2017, the 8th BPE (Basic Plan for Electricity Supply and Demand), Korea's new long-term energy plan aimed to increase the share of gas and renewables in the generation mix to 39% while lowering that of coal to 36% by 2030 in order to reduce emissions from power. The policy also aimed for a nuclear phase out, given safety concerns. **Figure 8-16** shows the recent increases in coal and gas use in electricity generation. It is expected that the reduction in nuclear and coal fuel sources will increase demand for gas further.

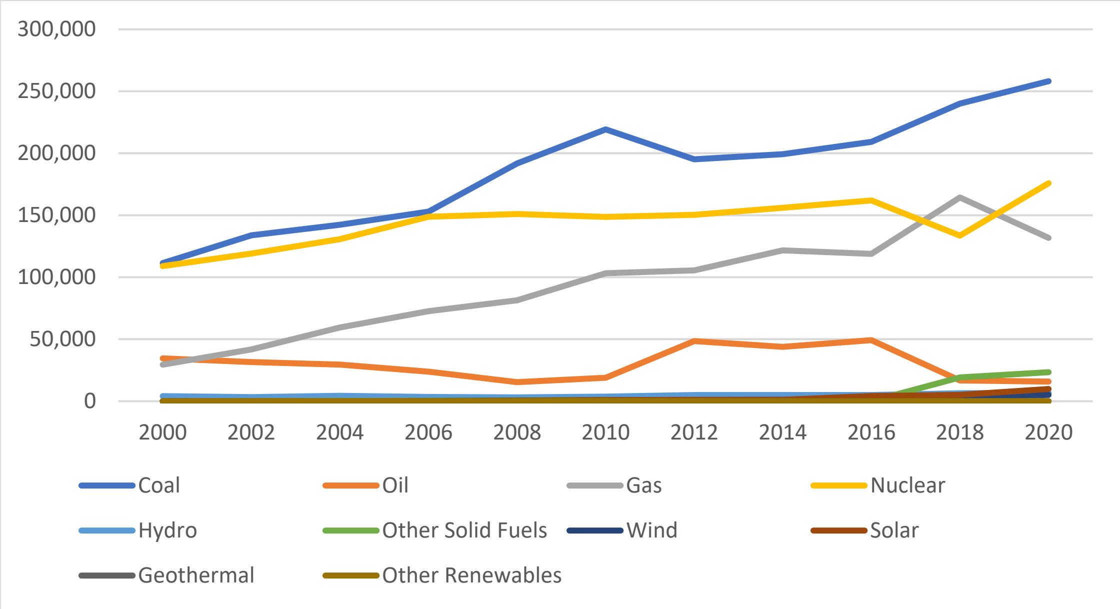



Figure 8-16: Electricity output (in GWh) in South Korea (Woodmac 2019)

Overall emissions levels in South Korea are expected to start tapering off after spiking in 2026, following the effective implementation of stricter policy controls over the use of coal including introduction of a carbon tax, inclusion of environmental costs in fuel cost, and an efficient Emissions Trading Scheme. The government is likely to shutdown 20 coal power plants which have been in operation for more than 30 years by 2034, leaving the gap to be filled in by LNG power plants amid Korea's 9th Basic Plan for Electricity supply and demand. In the process, the Korean government could also push for a new policy which can put a cap on coal power production, forcing coal power plants to compete within that limit. These measures will help South Korea in achieving is NDC pledges and targets (**Figure 8-17**).

| SOUTH KOREA | Main pledges and targets | Climate Action Tracker |
|---|---|---|
| PARIS AGREEMENT | Ratified | Yes |
| | 2030 unconditional target(s) | 37% below BAU by 2030<br>[78% above 1990 by 2030 excl. LULUCF]<br>[20% below 2010 by 2030 excl. LULUCF] |
| | Coverage | Economy-wide (including international market mechanisms) |

Figure 8-17: Paris Agreement Main Pledges and Targets – South Korea

Source: climateactiontracker.org

*China*

China's power generation mix is predominantly supplied by coal power (~65%) and is the second highest emitter of $CO_2$ in China's economy (**Figure 8-18**). China's 13th five-year plan focused on increasing the share of gas in the energy mix to 10% by 2020. However, it was still around 8% in 2019. Coal-to-gas switching in the power sector will enable emissions reduction and increase the share of gas. LNG will be a key source of supply for China as the gas demand grows. LNG consumption is expected to increase to ~110 bcm by 2024 compared to 74.7 bcm in 2019. A large part of this increased gas consumption is expected to go to heating, power and industry. If supportive coal-to-gas switching policies from the government continue, this would help further reduce emissions. A summary of China's NDC pledges and targets is provided in Figure 8-19.

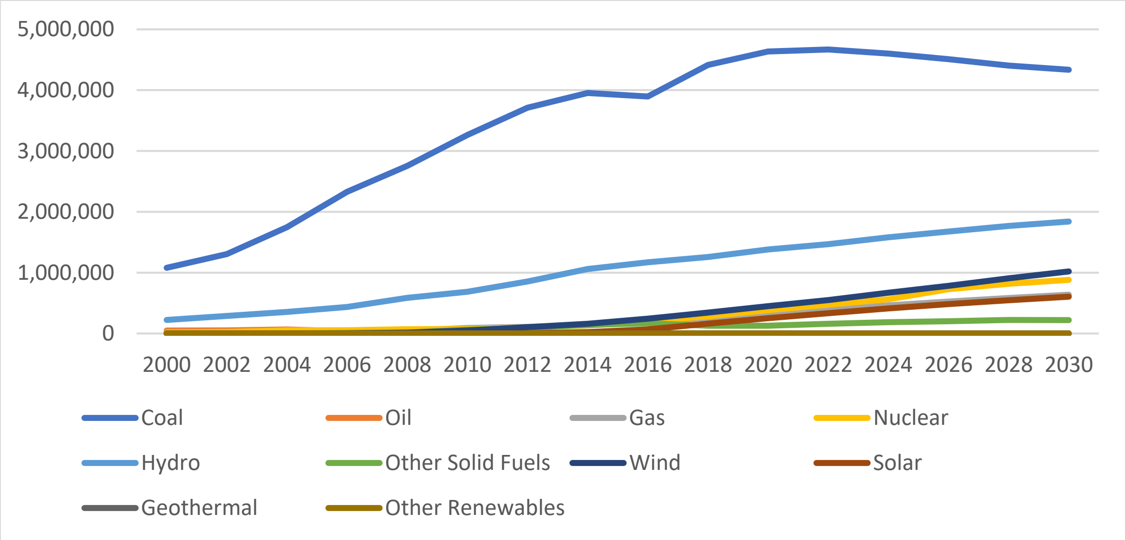



Figure 8-18: Electricity output (in GWh) in China (Woodmac 2019)

| CHINA | Summary of pledges and targets | |
|---|---|---|
| PARIS AGREEMENT | Ratified | Yes |
| | 2030 unconditional target(s) | Peak CO2 emissions latest by 2030<br>Non-fossil share: 20% in 2030<br>Forest stock: + 4.5 billion m³ by 2030 compared to 2005<br>Carbon Intensity: -60% to -65% below 2005 by 2030<br>[33–47% above 2010 by 2030 excl. LULUCF for peaking and non-fossil targets]<br>[36–53% above 2010 by 2030 excl. LULUCF for carbon intensity targets] |
| | Coverage | Economy-wide |
| | LULUCF | Unclear how LULUCF is included |

Figure 8-19: Paris Agreement Main Pledges and Targets – China

Source: climateactiontracker.org

The emissions targets and NDCs within these import markets should be considered as evidence of these countries' commitment to managing climate change through GHG emissions reduction. Therefore, any end-user emissions should be considered on a net basis based on the effectiveness of the jurisdictions' Nationally Determined Contributions (NDCs). It is not possible to measure the direct contribution of NDCs in reducing climate change impacts for the same reasons prohibiting the identification of a specific change in the environment from increased GHG emissions. It is likely there is a reduction in overall end-user emissions because of countries NDCs, however, it is not possible to establish the quantum of the reduction.

In conclusion, the Paris Agreement allows for variation in performance in accordance with the development status of the emitting country. The three most likely locations of end-users of Crux gas have been identified as having ratified the Paris Agreement and have volunteered NDC's aimed at decarbonising the energy market and keeping warming to less than 2ºC above pre-industrial levels. Further, the Paris Agreement includes mechanisms and a schedule for countries to increase the emission reduction targets within their jurisdiction.

**Substitution of Higher Intensity Fossil Fuels**

End-user impacts can be considered in terms of the energy transition to cleaner and affordable energy provision. Natural gas is a critical component of the energy transition - helping to meet increasing demand and improve air quality (IEA 2019) and, according to Australia's Chief Scientist, "making it possible for nations to transition to a reliable, and relatively low emission, electricity supply."[17]

Crux gas may have a lower net contribution than has been identified considering the potential net reduction in GHG emissions from coal-to-gas substitution. However, the reasons previously given for being unable to quantify the Crux contribution to an increase in global temperature also hold if trying to quantify the Crux project's net reduction in global temperatures. There are two other ways to evaluate the net reduction in emissions from coal-to-gas substitution; through comparison of emissions and emissions intensities.

In respect of total emissions, according to the *Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future* (the Final Report), available natural gas power generation technologies can reduce GHG emissions by 68% compared to current brown coal generation technologies and 61% compared to current black coal generation technologies (Commonwealth of Australia 2017a). In addition, compared to coal-fired power plants, modern natural gas-fired power plants emit less than one tenth of the pollutants (Shell 2019a). Australia's total LNG exports are estimated to have the potential to lower emissions in importing countries by around 148 $MtCO_{2-e}$ in 2018, if they displace coal consumption in those countries (Commonwealth of Australia 2019). As a recent example, the IEA concluded that coal-to-gas substitution helped avoid 100 $MtCO_{2-e}$ in 2019 following the avoidance of 95 $MtCO_{2-e}$ in 2018 (IEA, 2020). This evidence lends significant weight to the expectation that natural gas, including from sources such as Crux, will continue to lead to lower GHG concentrations than would otherwise be the case.

In terms of emissions intensities, a recent ERM study prepared for Woodside's Browse and Scarborough projects estimated that the Scarborough total lifecycle emissions intensity would be 480 kgCO2-e/MWh. The International Panel on Climate Change (IPCC) summarised the lifecycle emissions intensity of electricity from various emissions sources. This showed that the median emissions intensity of gas fuelled electricity was approximately 450 kgCO2-e/MWh. IPCC also show that oil and coal power electricity generates approximately 850 kgCO2-e/MWh and 1000 kgCO2-e/MWh respectively (IPCC 2011). This evidence demonstrates that gas is a lower emissions intensity fossil fuel than coal or oil so it is credible to suggest that coal/oil to gas substitution would result in a net reduction in climate related impacts.

The IEA also notes that other renewable sources of energy are also critical to accelerating this transition and that coal substitution by gas is a necessary but insufficient measure to reduce global temperature increases to less than 1.5°C above pre-industrial levels. Therefore, it is important to consider the future energy mix when considering the substitution of one energy source for another because substitution of even lower emission sources (i.e. coal-to-renewables substitution) would result in greater reductions.

The International Renewable Energy Agency (IRENA) publish information in two scenarios similar in concept to the STEPS and SDS scenarios published by the IEA. They are the Current Plan and the Energy Transformation scenario. The IRENA report

[17] https://www.chiefscientist.gov.au/news-and-media/national-press-club-address-orderly-transition-electric-planet

on Transforming the Energy System (2019) identifies that renewable energy and electrification could deliver up to 75% of emissions reductions (**Figure 8-20**) between these two scenarios and that fossil fuel demand will decrease by 64%, leaving fossil fuels likely to provide 36% of energy demand, by 2050 (**Figure 8-21**).

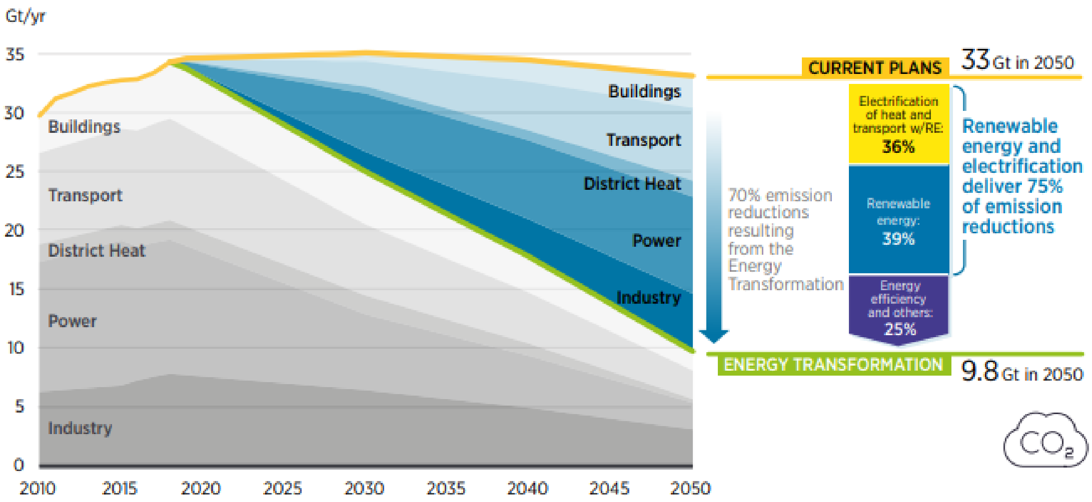



Figure 8-20: Annual energy related CO2 emissions and reductions, 2010-2050 (IRENA 2019)

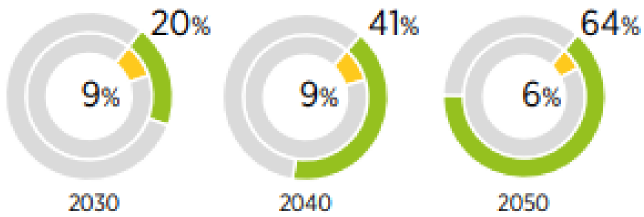



Figure 8-21: Total fossil-fuel demand reduction relative to 2019 in Current Plans and the Energy Transformation (IRENA 2019)

In their October 2019 fuel report, IEA identifies renewables as having an increasingly beneficial net reduction of global emissions, however the adoption of renewables requires that governments address three main challenges: 1) policy and regulatory uncertainty; 2) high investment risks in developing countries; and 3) system integration of wind and solar in some countries. In addition, the IPCC Special Report on the impacts for global warming of 1.5ºC above pre-industrial levels shows that society will continue to need some products that create emissions for the foreseeable future, because no other option is available yet (IPCC 2019).

It is apparent from the data that renewable energy sources and electrification are the long-term solution to emissions reduction and reducing global temperature increases to less than 1.5ºC above pre-industrial levels. It is also clear that this transition will take time, significant investment, positive policy intervention, and cross-sector collaboration. In short, renewable energy alone cannot currently meet energy demand and there will be a gap in the energy mix to be filled by existing sources up to 2050 and beyond, albeit in diminishing proportion.

### 8.4.5.13 Management of Impacts from End-User GHG Emissions

The evaluation of end-user impacts has established numerous sources of uncertainty in determining the effect on climate change of end-user emissions. These include:

- Speculation in identifying the increase in GHG emissions, global temperatures, and changes in an environment as a result of an end-user's emissions.

- Speculation in identifying changes to energy supply and demand as a result of major global disruption such as pandemics, conflicts, or geopolitical changes.
- The multitude of end-users, in different jurisdictions, with different combustion efficiencies and uses of gas.
- The extent to which gas will substitute for other gas or for coal and oil in the end-user jurisdiction.
- The extent to which gas will change the speed of adoption of renewable energy sources.
- The effectiveness of NDCs made under the Paris Agreement.
- The effectiveness of Shell Group's measures including those in place to address the previous uncertainties.

Measures to address these uncertainties are required to support a demonstration that end-user impacts will be managed to an acceptable level. Primary among those is the international legal framework implemented globally through the Paris Agreement.

In considering how can society meet the goal of the Paris Agreement it must be acknowledged that energy is a fundamental human need. It is essential for survival, for health and the benefits of modern life. Energy is needed for cooking, heating and cooling, for travel and all forms of economic activity. Every product bought or service used to make our lives better comes from a business or organisation that relies on energy. Energy enables opportunities for a growing population seeking to improve their quality of life. The world's population today is around 7.5 billion. By 2050 the UN expects the world population to be close to 10 billion. Society faces a dual challenge: how to make a transition to a low-carbon future to reduce the risks of climate change while also extending the economic and social benefits of energy to everyone on the planet.

The goal of the Paris Agreement is to hold 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. Achieving this will require a dramatic reduction in GHG emissions, reaching a point of net-zero global emissions within the second half of this century. It will require fundamental changes in the way energy is produced and used across the global economy. There are three ways to reduce global greenhouse gas emissions:

1. Improve energy productivity.
2. Change the mix of energy products used by society.
3. Store emissions in carbon sinks[18].

Only in combination will these deliver the full reduction in energy system emissions required to achieve the goals of the Paris Agreement. The international legal framework and a lack of control over end-user emissions does not preclude Shell from making a positive contribution to managing uncertainties associated with climate change impacts and contributing to society meeting the Paris Agreement targets. Given Shell does not have operational control over end-user emissions, the following measures are examples of how this uncertainty could be addressed by Shell Australia, in conjunction with the wider Shell Group and others.

[18] A sink is a mechanism to remove and store carbon dioxide from the system, either at the point of emission or by natural or technological removal from the atmosphere.

- **Working with the natural gas value chain to reduce methane emissions in third party systems** (e.g. regasification and distribution), for example, by encouraging others in the value chain to reduce methane emissions and become a signatory to the Methane Guiding Principles.
- **Promote and market the role of LNG in displacing higher carbon intensity fuels** for example, by promoting carbon neutral gas cargoes where customers can voluntarily offset the full life-cycle CO2-e emissions of an LNG cargo through the purchase of carbon credits. This can be achieved solely by the customer or jointly with Shell Group.
- **Continue to develop and deploy new technologies to substitute for higher carbon intensive fuels** for example by growing the New Energies business exploring low carbon technologies such as biofuels, hydrogen, solar and wind power, electric vehicle charging, and smart energy solutions.
- **Continue to advocate for stable policy frameworks that reduce carbon emissions** such as;
    - the Paris Agreement - which establishes global targets, a framework for global emissions management and a mechanism for increasing ambition over time through successive NDCs.
    - market mechanisms such as carbon pricing, together with targets based on science and measures to reduce the economic and social costs of energy transition so that frameworks endure.
- **Maintain membership of relevant international climate related business advocacy groups** such as International Union for the Conservation of Nature (IUCN), Energy Transitions Commission, International Emissions Trading Association, IPIECA, UN Global Compact, Oil and Gas Climate Initiative, and the World Business Council for Sustainable Development.
- **Continue to monitor, report, and adapt to the global energy outlook,** for example by:
    - monitoring developments in the global energy outlook and emerging regulatory change in order to adapt business plans and strategies for changing expectations, and to manage risk.
    - considering sensitivities across a range of variables, including commodity prices, carbon prices, length of asset life, exchange rates and interest rates when making investment decisions.
    - assessing collective progress toward meeting the Paris Agreement’s long-term goal informed by the agreement’s five-yearly "global stocktake". Shell Group will review its ambition based on this assessment of progress, revised scenarios, and NDCs.
    - inputting into the Shell Group Sustainability Report and Annual Report which monitors performance and reports progress towards its ambitions.

Shell Australia, as part of the wider Shell Group, is playing a role in working towards larger, group-level ambitions, which have been recently updated with the announcement in April 2020 of Shell Group’s ambition to be a net zero emissions energy business[19] by 2050 or sooner.

[19]As of the date of this document Shell Group’s operating plans and budgets do not reflect Shell Group’s Net-Zero Emissions ambition. Shell Group’s aim is that, in the future, its operating plans and budgets will change to reflect this movement towards its new Net-Zero Emissions ambition. However, these plans and

The context for the Shell Group announcement was the recognition that for society to achieve a 1.5° Celsius future, the world is likely to need to stop adding to the stock of greenhouse gases in the atmosphere – a state known as net-zero emissions – by around 2060. But those who can move faster, must move faster – advanced parts of the world are likely to need to reach that point by 2050.

Shell Group currently proposes to work towards this ambition in three ways, in step with society:

- an ambition to be net zero on all the emissions from the manufacture of all its products (scope one and two) by 2050 at the latest;
- accelerating Shell's Net Carbon Footprint ambition to be in step with society's aim to limit the average temperature rise to 1.5 degrees Celsius in line with the goals of the Paris Agreement on Climate Change;
- a pivot towards serving businesses and sectors that by 2050 are also net-zero emissions.

Shell Group's aim is that, in the future, its operating plans will change to reflect this net zero ambition.

Examples of current Group-level initiatives aimed at addressing uncertainty and contributing to society achieving the goals of the Paris Agreement targets are:

- unconditional three-year target (to 2022) to reduce its Net Carbon Footprint[20] against the 2016 baseline by 3-4%, linked to remuneration for more than 16,500 staff. It is intended that this target setting will be done annually, with each year's target covering a three-year period;
- continued growth of the New Energies business, having already invested in a range of low-carbon technologies, from biofuels, hydrogen and wind power, to electric vehicle charging and smart energy storage solutions.
- monitoring and reporting on Shell Group performance. Every five years, the Shell Group proposes to assess collective progress toward meeting the Paris Agreement's long-term goal informed by the agreement's five-yearly "global stocktake". Shell Group will review its ambition based on this assessment of progress, revised scenarios, and NDCs. Inherent in this review will be an appraisal of developments in technology and policy.  The first five-year review is currently anticipated to take place after 2021.
- developing scenarios.  Shell Group has been developing possible visions of the future since the 1970s. Shell Scenarios21 ask, "what if?" questions encouraging leaders to consider events that may only be remote possibilities and stretch their thinking. These scenarios also help governments, academia and business in understanding possibilities and uncertainties ahead. For example, Shell has built a scenario looking at what the EU might do to decarbonise energy in the next 30 years. It explores a possible, but highly demanding pathway to help

[20] Shell Group's "Net Carbon Footprint", includes Shell Group's carbon emissions from the production of its energy products, its suppliers' carbon emissions in supplying energy for that production and its customers' carbon emissions associated with their use of the energy products it sells. Shell Group only controls its own emissions. The use of the term "Net Carbon Footprint" is for convenience only and not intended to suggest these emissions are those of Shell Group or its subsidiaries.

[21] These scenarios are a part of an ongoing process used in Shell Group for over 40 years to challenge executives' perspectives on the future business environment. They are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes.

achieve a climate-neutral EU by 2050 – including deployment of clean technologies and shifting choices to support a green economy.

Shell Group's business plans will change over time in step with society's progress towards meeting the Paris Agreement. Further information and examples of how the Shell Group is playing a role in the energy transition is available on the website (www.shell.com).

**End-user GHG Emissions Conclusion**

It is known that increasing levels of GHG in the atmosphere contributes to the warming of the climate system. The evaluation considers that end-user use of gas for energy results in increased GHG emissions, which contribute to climate change. Governments, consumers and energy producers alike have a role to play to mitigate these impacts and Shell is committed to show leadership towards a decarbonised economy.

International frameworks are set up to encourage nations to increase their emission reduction ambitions, support the commercial availability of low-carbon technologies, and collaborate to bring clean, affordable energy to consumers everywhere. However, the end-user impacts can be modified by increasing the supply of clean and affordable energy products and through companies playing a role in the decarbonisation of the energy system. Shell Australia, as a member of the Shell Group supports the goals of the Paris Agreement, and wants to play its part and contribute to the global effort to tackle climate change and help society meet the goals of the Paris Agreement. As a business that supplies energy, Shell Group intends to work with sectors which use energy to help identify and enable decarbonisation pathways for them to follow towards a net-zero emissions future.

It has been determined that the international frameworks are adaptable in how to reach their goals and the burden for the transition is shared between developed and developing countries. It has also been shown that gas plays a critical role in a net reduction in global emissions as part of the transition to a lower carbon energy system.

In conclusion, the environmental impacts from scope 3 GHG emissions are of an acceptable level because:

- The world (and the likely import markets for Crux gas) needs more energy;
- Renewable energies alone cannot meet current energy needs, and probably cannot meet projected energy needs, before the end of the Crux project, in 2065;
- Gas is the best alternative to fill the gap because it:
    - is a reliable energy source compatible with existing infrastructure;
    - has lower emissions than other fossil fuels;
    - can partner with renewable energies to promote earlier adoption; and
    - supports countries in reaching net-zero emissions targets.
- Developing the Crux project contributes to lower net global GHG emissions than would otherwise be the case if Crux were not developed;
- The end-user emissions are not inconsistent with the goals of the Paris Agreement, have been assessed, and will be mitigated by the jurisdiction in which they occur; and
- Shell Australia, is part of the Shell Group, which is working toward its ambitions to contribute to the global effort to tackle climate change and help society meet the goals of the Paris Agreement.

### 8.4.5.14 Risk and Impact Summary Table

Table 8-32: Crux GHG Emissions Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Planned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Magnitude | Sensitivity | Residual Impact |
| **Evaluation – Impacts** | | | | | | | |
| End-user impacts resulting from GHG emissions from the combustion of gas, including contribution to the incremental build-up of GHG in the atmosphere | X | X | X | X | Minor effect | Low | Minor |
| ***Key Management Measures*** | | | | | | | |

Shell does not have operational control over end-user emissions.

Shell Australia will ensure that programs are developed and implemented, in conjunction with the wider Shell Group and others, to actively support the global transition to a lower carbon future by net displacement of higher carbon intensity energy sources relating to third party GHG emissions which may include the following:

- Working with the natural gas value chain to reduce methane emissions in third party systems
- Promote and market the role of LNG in displacing higher carbon intensity fuels
- Continue to develop and deploy new technologies to substitute for higher carbon intensive fuels
- Continue to advocate for stable policy frameworks that reduce carbon emissions
- Maintain membership of relevant international climate related business advocacy groups
- Continue to monitor, report, and adapt to the global energy outlook

### 8.4.5.15 Acceptability of Impacts and Risks

The acceptable level of impact for the receptors that may credibly be impacted or at risk from the GHG emissions aspect of the Crux project is summarised in **Table 8-33**. The methods by which this acceptable level was determined, along with a justification as to why it is acceptable, are discussed in **Section 5.7**.

Table 8-33: Acceptable Levels of Impacts from End-User GHG Emissions

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| All | Australian environment | No significant impacts to the Australian environment attributable to the Crux project. | Yes. The management of end-user emissions is consistent with global legal frameworks and these are monitored for effectiveness and sufficiency.<br>Gas plays a key role in the transition to a lower carbon energy system by displacing demand for higher emitting products (e.g. coal). A net reduction in emissions is inherently acceptable. Uncertainty in substitution of Crux gas for coal is managed by the global efforts to decarbonise energy markets. |

**Principles of Ecologically Sustainable Development (ESD)**

Based on the impact assessment end-user GHG emissions are consistent with the Paris Agreement and the principles of ESD by:

- meeting existing end-user demand for energy;
- contributing to lower net global GHG emissions than would otherwise be the case if Crux were not developed;
- facilitating the distribution of lower carbon energy to meet the UN sustainable development goals, in particular;
  - affordable and clean energy;
  - climate action;
  - no poverty; and
  - decent work and economic growth.
- the consideration and integration of both long and short-term economic, environmental, social and equity considerations in the Paris Agreement;
- managing uncertainty in the assessment of impacts through initiatives supported by Shell Australia as part of the wider Shell Group's contributions to the global effort to tackle climate change and help society meet the goals of the Paris Agreement;
- applying the precautionary principle , and adopting mitigation measures in the absence of full scientific certainty; and
- considering global policies and actions related to GHG emissions and complying with Australian legislation that supports these policies .

**Matters of National Environmental Significance**

There is no clear and convincing evidence that GHG emissions from end-users of the Crux gas will result in significant impacts to threatened or migratory species. There is no clear and convincing evidence that the GHG emissions from end-users lead to environmental impact that exceed any of the significant impact criteria provided in **Table 7-1**.

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and corporate requirements. The environmental performance outcome will be amended overtime to account for changes in external and internal context through the Environment Plan approval process.

**Acceptability Summary**

The assessment of impacts from end-user GHG emissions determined the residual impact ratings was minor (**Table 8-33**). As outlined above, the acceptability of the impacts and risks from GHG emissions associated with the Crux project has been considered in the context of, ESD, relevant legislative requirements, external context, and internal context (i.e. Shell requirements). Based on the evaluation of impacts, Shell considered the end-user impacts to be of an acceptable level.

### 8.4.5.16 Environmental Performance Outcomes

Shell Australia will ensure that programs are developed and implemented, in conjunction with the wider Shell Group and others, to actively support the global transition to a lower carbon future by net displacement of higher carbon intensity energy sources relating to third party GHG emissions.

### 8.4.6 Invasive Marine Species

#### 8.4.6.1 Project Context

Aspects of the Crux project have the potential to introduce IMS to the project area, which may interact with environmental receptors. These aspects are described in **Section 5.7.6** and include:

- biofouling on the drilling rig, vessels and equipment sourced from outside Australian waters that will be immersed in the marine environment (e.g. drilling equipment, drilling rig anchors)
- ballast water discharges from vessels and drilling rigs, and
- transfer of IMS from the Prelude FLNG facility to the Crux flexible riser.

These aspects constitute potential vectors by which IMS may be introduced into the project area.

Establishment of IMS in the Crux project requires a sequence of events to occur:

- the potential IMS must be present on (e.g. biofouling) or in (e.g. ballast water) the vector
- the potential IMS must be released into the environment (e.g. ballast water discharge, release of propagules from biofouling), and
- the potential IMS must survive and reproduce (either sexual or vegetative reproduction) in the natural environment.

The introduction of IMS is recognised globally as a threat to marine biodiversity, and the International Maritime Organization (IMO) has developed guidelines for the management of biofouling and ballast water. Commonwealth, State and Territory authorities also regulate the risk of IMS from biofouling and ballast water. Vessels operating in Australia are required to meet these requirements, and vessels meeting these requirements pose an inherently low risk of harbouring IMS or releasing IMS into the environment.

The materials for the construction of the Crux infrastructure (e.g. platform, flowlines, risers, export pipeline etc.) will be new material that has not previously been submerged. Such materials will not host potential IMS and do not pose a direct biosecurity risk.

The offshore environment of the project area is relatively deep, and hard substrate habitats are very uncommon. Many potential IMS are sessile invertebrates that require hard substrate for attachment. In the unlikely event potential IMS are released into the project area, the IMS are unlikely to encounter suitable substrate for recruitment. Most potential IMS are adapted to coastal waters, such as ports and harbours. If a potential IMS were to become established in the project area, it is unlikely to survive in the relatively deep water offshore environment.

Spread of IMS along the Crux flexible riser to the export pipeline is not considered credible due to the water depth of the export pipeline. Credible potential IMS on the riser will be restricted to the part of the riser in surface waters at the Prelude FLNG facility (i.e. the immediate vicinity of the Prelude FLNG facility). The IMS species (*Didemnum perlucidum*, a sea squirt) observed as growing on the Prelude FLNG facility hull has been recorded at depths of up to 8 m (B. Tilley 2013, pers. comm., cited in Muňoz and McDonald 2014). However, it is typically found in the upper water column (1 m – 3 m) (Muñoz et al. 2013, cited in Muňoz and McDonald 2014).

If potential IMS become established in the project area (i.e. on the Crux platform or the flexible riser connected to the Prelude FLNG), these IMS may become established on support vessels. These vessels may subsequently provide vectors for translocation of potential IMS. This sequence of events is considered extremely remote given the controls that are routinely applied to support vessels (e.g. anti-fouling coating, inspections, hull cleaning etc.), the remote offshore location and nature of typical vessel activities (e.g. short periods alongside the Crux platform during operations). Additionally, Shell have developed and implemented a targeted surveillance/monitoring and biosecurity management program for IMS on the Prelude FLNG facility to proactively manage IMS risks associated with the transfer of IMS from the Prelude riser to the surrounding environment and other infrastructure (e.g. Crux flexible riser or vessels).

#### 8.4.6.2 Description and Evaluation of Impacts and Risks

A range of environmental sensitivities within the following groups may be at risk from the introduction of potential IMS, including:

- ecosystems, communities and habitats
- threatened species and ecological communities, and
- socio-economic and cultural environment.

Potential impacts and risks associated with aspects of the Crux project with these are discussed below. As outlined in **Section 8.3.3**, the assessment considers only the residual impacts and risks following the application of controls.

**Ecosystems, Communities and Habitats**

*Benthic Communities*

Benthic communities within the project area are characterised by relatively sparse assemblages of filter feeding and deposit feeding organisms. The seabed within the entire project area does not receive sufficient photosynthetically active radiation to support benthic primary producer habitat, such as macroalgae and zooxanthellate corals. Very few potential IMS identified can credibly survive in the water depths of the project area. For example, of the non-oceanic species identified in the Australian Marine Pest Monitoring Manual (Department of Agriculture, Fisheries and Forestry 2010) indicated very few IMS (aside from planktonic oceanic species such as dinoflagellates) could credibly survive in the project area; only three (European clam, soft-shell clam and Northern Pacific sea star) were identified as potentially surviving in > 90 m water depth; none were identified as credibly surviving at > 200 m water depth. These three species are typically found in shallow, coastal waters. As outlined above, the IMS species known to occur on the Prelude FLNG facility hull only occurs in water depths up to 8 m (Muňoz and McDonald 2014). The project area is > 90 m water depth, with most of the area > 150 m water depth. In the highly unlikely event these species were introduced into the project area, they are unlikely to survive or become established due to the water depth.

Following construction of the Crux platform, it is possible that potential IMS may become established on the artificial habitat provided by the platform jacket and risers. However, this is considered highly unlikely as the potential vectors (e.g. vessels) will typically be near the platform for relatively short periods (up to a week) during the operational phase. In the unlikely event an IMS becomes established on the platform jacket, it is highly unlikely it will spread in the environment due to the water depth and remoteness of the area. Further, platform support vessels will typically be sourced from Australian waters; Australian ports are generally considered to pose a low risk of harbouring potential IMS compared to ports in other countries in the region (e.g. Indonesia and Singapore).

Most species within the project area will be widely distributed as similar habitats are broadly represented in the Timor Sea. An IMS may compete with native species if it were to become established in the project area. This may decrease the species diversity of benthic communities.

IMS are typically extremely difficult to eradicate once established and reproducing in an area. In the highly unlikely event an IMS becomes established in the project area, it would be almost impossible to remove.

*Shoals and Banks*

The shoals and banks in the region are typically shallower than the project area. As outlined above in **Benthic Communities**, most potential IMS prefer shallower habitats than the project area. Hence, shoals and banks in the region may be more vulnerable to introduction of IMS, although the shoals and banks are also below the preferred depth range of many potential IMS.

The nearest shoal to the proposed location of the Crux platform is Goeree Shoal, which lies approximately 13 km to the north-west. Project vessels are very unlikely to spend any significant time in proximity to Goeree Shoal (or any other bank or shoal), and direct introduction of IMS to a shoal or bank is considered very unlikely.

In the highly unlikely event an IMS is introduced and becomes established in the project area, the IMS distribution may extend to include shoals and banks. Potential impacts to shoals and banks are expected to be similar to **Benthic Communities**, namely a potential reduction in species diversity.

*Key Ecological Features*

The continental slope demersal fish communities KEF overlaps the export pipeline corridor. The depth of this overlapping area is > 200 m, which is too deep for IMS to credibly become established. No impacts to the environmental values of this KEF will credibly occur due to potential IMS.

**Threatened Species and Ecological Communities**

None of the EPBC Act listed threatened or migratory species will credibly be impacted in the unlikely event of an IMS introduction resulting from the Crux project. IMS are not identified as a threatening process for EPBC listed threatened or migratory species that may occur within the project area.

**Socio-economic and Cultural Environment**

*Offshore Petroleum Exploration and Operations*

The only socio-economic or cultural receptor within the project area that may credibly be impacted by the introduction of an IMS is the Prelude FLNG facility. The potential for IMS introduction to the Prelude FLNG facility from a project vessel is extremely unlikely.

Some potential IMS, such as green mussels, have been shown to form dense aggregations in pipes, such as seawater intakes for process cooling. Marine growth is a common problem on offshore facilities. It is routinely managed by cleaning or the use of biocides to reduce or remove marine growth. As such, impacts to the Prelude FLNG facility from an IMS introduction are not considered credible.

### 8.4.6.3 Risk and Impact Summary and Key Management Controls

Table 8-34: IMS Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Unplanned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Significance | Likelihood | Residual Risk |
| **Evaluation – Unplanned** | | | | | | | |
| Unplanned risks associated with the introduction of IMS as a result of the Crux project | | | X | X | Major | Extremely remote | Moderate |

| ***Key Management Controls*** |
|---|
| Ballast water exchange operations will comply with the IMO International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (as appropriate to vessel class), Australian Ballast Water Management Requirements (DAWR 2017) , *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* and *Biosecurity Act 2015*, including:<br>• all ballast water exchanges conducted > 12 nm from land<br>• vessel Ballast Water Management Plan stipulating that ballast water exchange records will be maintained, and<br>• completion of DAWR Ballast Water Management Summary sheet for any ballast water discharge in Australian waters).<br>Biofouling management for vessels in accordance to the IMO Guidelines for the Control and Management of Ships Biofouling to Minimise the Transfer of Invasive Aquatic Species.<br>The International Convention on the Control of Harmful Anti-fouling Systems on Ships will be complied with, including vessels (of appropriate class) having a valid International Anti-fouling Systems Certificate.<br>Compliance with the Commonwealth *Biosecurity Act 2015,* WA *Fish Resources Management Act 1994* and *Aquatic Resources Management Act 2016*, NT *Fisheries Act* and associated regulations.<br>Alignment with the *National biofouling management guidance for the petroleum production and exploration industry* and the WA DPIRD *Biofouling Biosecurity Policy.*<br>Maintenance of a minimum 1 km buffer from shoals within the in-field development area (**Figure 5-3**).<br>The Crux platform and jacket will not be wet towed to the Crux in-field development area. |

### 8.4.6.4 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be at risk from the IMS aspect of the Crux project are summarised in **Table 8-35**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks that may result from the IMS aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the IMS aspect of the Crux project is provided below.

Table 8-35: Acceptable Levels of Impacts and Risks from IMS

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Ecosystems, Communities and Habitats | Benthic communities | No significant impacts to benthic habitats and communities.<br>Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | Yes. The introduction of an IMS as a result of the Crux project is unlikely to survive given the water depth of the Crux project area. Shell will take industry-standard measures to reduce the likelihood of an IMS being introduced as a result of the Crux project. If an IMS were to be become established, it would be very difficult to eliminate, however it is unlikely to result in significant impacts to benthic habitats and communities. |
| | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of coral communities at named banks or shoals as a result of indirect/offsite[22] impacts associated with the Crux project. | Yes. While the shoals are likely to be more susceptible to an IMS becoming established due to their relatively shallow depth, the implementation of a 1 km buffer around the shoals makes the likelihood of an IMS becoming established extremely low. Shell will take industry-standard measures to reduce the likelihood of an IMS being introduced as a result of the Crux project. |
| | Key Ecological Features | No significant impacts to environmental values of KEFs. | Yes. The portion of the continental slope demersal fish communities KEF within the Crux project area is small (approximately 0.04%) and relatively deep (>150 m water depth). In the unlikely event an IMS was introduced, it would be very unlikely to survive. |

**Principles of ESD**

The risks and impacts from the introduction of IMS resulting from the Crux project are inherently inconsistent with some of the principles of ESD based on the following:

- the introduction of an IMS poses a risk to the biological diversity and ecological integrity of benthic communities in the vicinity of the Crux project.

Shell will apply a range of controls to ensure that the risk of IMS introduction is reduced to a level that is acceptable and ALARP. These include a range of industry best practices that have been developed through extensive industry experience preventing establishment and managing incursions of IMS. Following successful application of these controls, Shell considers the residual risk to be consistent with the principles of ESD.

[22] As defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoE 2013a).

**Relevant Requirements**

Management of the impacts and risks from an introduction of IMS resulting from the Crux project are consistent with relevant legislative requirements, including:

- compliance with international maritime conventions, including
  - The International Convention for the Control and Management of Ships' Ballast Water and Sediments
  - The International Convention on the Control of Harmful Anti-Fouling Substances, and
  - IMO 2011 Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species.
- compliance with Australian legislation and requirements, including:
  - *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006*:
    - Marine Order 98 – Marine Pollution prevention – anti-fouling systems
  - *Biosecurity Act 2015*:
    - National Biofouling Management Guidelines, and
    - Australian Ballast Water Management Requirements.
  - NT *Fisheries Act*
  - WA *Fish Resources Management Act 1994*, subsequent Fish Resources Management Regulations 1995 and the *Aquatic Resources Management Act 2016*, and
  - the WA DPIRD Biofouling Biosecurity Policy.

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The policies, strategies, guidelines, conservation advice and recovery plans for MNES that may occur within the potential area affected by an IMS do not identify IMS as a threat.

*Commonwealth Marine Environment*

The impacts and risks from the introduction of IMS will not result in impacts to the environmental values of the continental slope demersal fish communities KEF.

Introduction of IMS as a result of the Crux project will not credibly impact upon AMPs.

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from the introduction of IMS as a result of the Crux project determined the residual impact and risk rating was Moderate or lower (**Table 8-34**). As outlined above, the acceptability of the impacts and risks from the introduction of IMS as a result of the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and

- internal context (i.e. Shell requirements).

The residual impacts and risks are moderate. Shell considers residual impacts of moderate to be acceptable if (**Section 7**):

- all practicable measures have been identified commensurate with the risks and impacts
- internal context – the proposed controls and residual risk level are consistent with Shell policies, procedures and standards
- external context – consideration of the environment consequence and stakeholder expectations, and
- other requirements – the proposed controls and residual risk level are consistent with national and international standards, laws and policies.

The discussion above demonstrates that these requirements have been met in relation to the risk of IMS introduction for the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from the introduction of IMS from the Crux project to be acceptable.

#### 8.4.6.5 Environmental Performance Outcomes

**Ecosystems, Communities and Habitats**

No IMS of concern[23] established in the natural environment as a result of the Crux project.

No introduction of IMS to the marine environment from ballast water exchange operations undertaken or biofouling by project vessels.

[23] IMS of concern are species that are listed on the Western Australian Prevention List for Introduced Marine Pests or Commonwealth National Introduced Marine Pest Information System, and could survive in the natural environment beyond the Crux project infrastructure.

### 8.4.7 Waste Management

#### 8.4.7.1 Project Context

A range of aspects of the Crux project will result in the generation of hazardous and non-hazardous wastes and recyclable materials during all phases of the Crux project. These will include domestic wastes (e.g. recyclable material such as glass, plastics, paper and cardboard) and industrial wastes (e.g. waste lubricants, used filters and chemical storage materials). These will be routinely transported to shore for recycling or disposal. The planned management of these wastes will not result in any impacts to the offshore marine environment; however, improper storage and handling of these solid wastes may result in accidental releases to the marine environment. These unplanned events may result in risks and impacts to the marine environment. Shell's extensive operational experience indicates most accidental releases of solid wastes to the marine environment are typically relatively small, one-off events.

Some waste streams are discharged to the marine environment. Examples include utility discharges (e.g. sewage, putrescible waste), pipeline hydrotest discharge and PFW, drilling fluids and cuttings. Refer to **Section 8.4.8** for a discussion of planned waste discharges to the marine environment. Minor accidental releases of liquid wastes may also occur; these are also considered in **Section 8.4.8**.

The potential environmental impacts from the loss of solid wastes to the marine environment depend on the nature and amount of the waste, and the sensitivity of the environmental receptors that may be impacted. Some non-hazardous wastes such as paper and cardboard will readily degrade in the marine environment and pose little environmental risk. Other non-hazardous wastes are more persistent in the environment, particularly plastics. Hazardous wastes in the marine environment may result in acute and chronic toxic effects or accumulate in sediments. Accidental loss of solid waste to the environment is most likely to occur at the Crux platform location but may credibly occur anywhere within the project area. Shell has applied the precautionary principle and considered the loss of solid waste for the entire project area.

#### 8.4.7.2 Description and Evaluation of Impacts and Risks

**Physical Environment**

The loss of hazardous and non-hazardous solid waste may have a localised, temporary effect on water and sediment quality, depending on the nature of the waste. Chemicals (e.g. oiled wastes, solid chemicals etc.) may result in acute toxic effects, however given the offshore receiving environment and the nature of most potential waste spills, any such effects will be of short duration and highly localised.

**Ecosystems, Communities and Habitats**

The potential for accidental spills of hazardous and non-hazardous solid wastes to impact upon ecosystems, communities and habitats is considered remote. Habitats within the project area are not considered to be particularly sensitive and are well represented in the region. Accidental loss of hazardous and non-hazardous solid wastes will not credibly result in impacts to the shoals and banks in the region.

The continental slope demersal fish communities KEF is partially overlapped by the export pipeline corridor. Physical habitat modification has been identified as a threat for this KEF, however fishing gear (particularly trawl fishing) is the associated threatening process.

**Threatened Species and Ecological Communities**

*Key Fauna Species*

Marine debris has been identified as a threat for a range of vertebrate fauna species, including marine turtles, birds, marine mammals and sharks and rays. Marine debris is listed as a key threatening process under the EPBC Act. Persistent wastes such as plastics are of concern, as the threat to fauna may remain long after the waste is spilled. Potential impacts of marine debris on key fauna species include (DEWHA 2009c):

- entanglement, potentially resulting in restricted mobility, drowning, starvation, smothering and wounding
- ingestion (particularly of plastics) leading to physical blockage of digestive systems, leading to starvation, and
- acute or chronic toxic effects.

Given the typically small volumes of hazardous or non-hazardous wastes released, potential impacts to key fauna species are expected to be restricted to individual animals. Many of the vertebrate species considered vulnerable to wastes occur seasonally or are expected to occur in low densities (e.g. transiting the area).

### 8.4.7.3 Risk and Impact Summary and Key Management Controls

Table 8-36: Waste Management Evaluation of Impacts and Risks

| **Project Component/ Activity** | **Environmental Value/Sensitivity** | | | | **Evaluation – Unplanned** | | |
|---|---|---|---|---|---|---|---|
| | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Significance** | **Likelihood** | **Residual Impact** |
| **Evaluation – Unplanned Risks** | | | | | | | |
| Unplanned risks resulting from an accidental release of hazardous or non-hazardous solid waste to the marine environment | X | X | X | | Slight | Medium | Slight |
| ***Key Management Controls*** | | | | | | | |
| All discharge of waste from vessels will comply with relevant MARPOL 73/78, *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution) Act 1983* and subsequent Marine Order requirements (as appropriate for vessel classification).<br>Waste management procedures will be implemented for the Crux project that:<br>• provide for waste segregation and storage<br>• safe handling and transport of waste<br>• appropriate waste classification and disposal, recycling and landfill<br>The disposal of non-hazardous and hazardous wastes will be tracked to confirm they are disposed of at an appropriately licensed waste facility.<br>The management and disposal of any quarantine risk material will be in accordance with relevant requirements of the *Biosecurity Act 2015*. | | | | | | | |

#### 8.4.7.4 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the waste management aspect of the Crux project are summarised in **Table 8-37**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the waste management aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the waste management aspect of the Crux project is provided below.

Table 8-37: Acceptable Levels of Impacts and Risks from Waste Management

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
| --- | --- | --- | --- |
| Threatened Species and Ecological Communities | Key fauna species | No mortality or injury of threatened or migratory MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory MNES fauna. | Yes. Shell implements MARPOL standards in relation to managing wastes, which reduce the likelihood of wastes being accidentally released to the marine environment. Given the remote location of the Crux in-field development area, any accidental release of wastes to the environment would not be expected to interact with a large number of threatened or migratory MNES species. |

**Principles of ESD**

The risks and impacts from wastes are consistent with the principles of ESD based on:

- the environmental values/sensitivities within the project area are not expected to be significantly impacted, and
- the precautionary principle has been applied to the risk assessment.

**Relevant Requirements**

Management of the impacts and risks from wastes during the Crux project are consistent with relevant legislative requirements, including:

- compliance with international maritime conventions, including:
  - MARPOL:
    - Annex V: regulations for the prevention of pollution by garbage from ships.
- compliance with Australian legislation and requirements, including:
  - *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution) Act 1983*:
    - Marine Order 94 – Marine pollution prevention – packaged harmful substances, and
    - Marine Order 95 – Marine pollution prevention – garbage.
- management of impacts and risks are consistent with policies, strategies, guidelines, conservation advice, and recovery plans for threatened species (**Table 8-38**).

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates significant impacts[24] to threatened and migratory species will not result from the unplanned direct impacts from the waste management aspect of the Crux project.

An unplanned release of waste into the marine environment is unlikely to occur and may result in injury to or death of individual animals. This unplanned event is not considered to have the potential for significant impacts to threatened or migratory species due to the low likelihood of wastes being released and the limited number of animals that would potentially be impacted.

Alignment of the Crux project with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided in **Table 8-38**.

*Commonwealth Marine Environment*

The impacts and risks from the waste management aspect of the Crux project on the Commonwealth marine environment do not exceed any of the significant impact criteria provided in **Table 7-1**.

The impacts and risks from the accidental loss of hazardous and non-hazardous solid waste during the Crux project on the continental slope demersal fish communities do not significantly affect the environmental values of the KEF.

[24] as described in Matters of National Environmental Significance - Significant impact guidelines (DoE 2013a)

Table 8-38: Summary of Alignment of the Impacts and Risks from Waste Management with Relevant Requirements for EPBC Threatened Fauna

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| All vertebrate fauna | Threat abatement plan for the impacts of marine debris on vertebrate marine life (DEWHA 2009c) | Marine debris | The Crux project will manage waste in accordance with standard maritime requirements, international conventions (MARPOL), relevant Marine Orders and Shell's internal management system requirements. This management reduces the likelihood of the accidental release of hazardous and non-hazardous wastes into the marine environment.<br>The quantities and nature of wastes that may be accidentally released into the environment are unlikely to result in significant impacts to threatened or migratory species. |
| Marine mammals | Conservation advice on sei whale (*Balaenoptera borealis*) (DoE 2015c) | Pollution (persistent toxic pollutants) | |
| | Conservation advice on fin whale (*Balaenoptera physalus*) (DoE 2015d) | Pollution (persistent toxic pollutants) | |
| | Conservation management plan for the blue whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* 2015–2025 (Commonwealth of Australia 2015a) | Habitat modification including presence of oil and gas platforms/rigs, marine debris infrastructure and acute/chronic chemical discharge | |
| | Conservation advice on humpback whale (*Megaptera novaeangliae*) (DoE 2015b) | Entanglement – marine debris | |
| | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Marine debris | |
| Marine reptiles | Recovery Plan for Marine Turtles in Australia 2017– 2027 (Commonwealth of Australia 2017b) | Marine debris | |
| | Conservation advice on leatherback turtle (*Dermochelys coriacea*) (DEWHA 2009a) | Marine debris | |
| | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Marine debris | |
| Sharks and rays | Conservation advice on whale shark (*Rhincodon typus*) (DoE 2015l) | Marine debris | |
| | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Marine debris | |
| Commonwealth marine environment | Significant Impact Guidelines for the Commonwealth marine environment (**Table 7-1**) | Marine debris | The impact assessment indicates that the waste management aspect of the Crux project will not exceed the Commonwealth marine environment significant impact criteria provided in **Table 7-1**. |

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from underwater noise determined the residual impact and risk rankings were all minor or lower (**Table 8-36**). As outlined above, the acceptability of the impacts and risks from the accidental loss of hazardous and non-hazardous solid waste during the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are slight. Shell considers residual impacts of minor or lower (i.e. slight) to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to waste management aspect of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from the accidental loss of hazardous and non-hazardous solid waste during the Crux project to be acceptable.

### 8.4.7.5 Environmental Performance Outcomes

**Threatened Species and Ecological Communities**

No mortality or injury of threatened and migratory MNES species as a result of unplanned waste discharge to sea during the Crux project.

### 8.4.8 Liquid Discharges

#### 8.4.8.1 Project Context

A range of aspects of the Crux project will result in the discharge of liquid waste streams to the marine environment. These aspects are described in **Section 5.7.1** and include:

- PFW
- wastewater
- cooling water
- hydrotest water
- drilling fluids and cuttings, and
- minor accidental releases of chemicals/hydrocarbons to the environment.

Descriptions of the characteristics of each of these liquid discharge streams are provided in **Table 8-39**. Note that accidental releases with a moderate or greater consequence magnitude are considered separately in **Section 8.4.9**. These spills are primarily large volume accidental hydrocarbon releases that have the potential to cause widespread environmental damage.

A number of other small planned or accidental liquid discharges may occur during the project life, including hydraulic fluids from the BOP and excess cement during development drilling, lubrication fluids from planned maintenance of the subsea integration system and flushing fluids associated with decommissioning activities. These discharges are expected to be for a short duration and/or relatively minor in nature. Therefore, any potential impacts are expected to occur within the area influenced by the larger planned discharges and are unlikely to result in impacts to the environment that are not assessed within this OPP. The full range of potential planned discharge sources will be further assessed and defined as the engineering design progresses and detailed in activity-specific EPs.

Table 8-39: Summary of Key Liquid Discharge Stream Characteristics

| Discharge Stream | Description | Discharge Location | Project Stage and Duration | Indicative Volume* |
|---|---|---|---|---|
| PFW | PFW consists of water recovered from the reservoir along with the hydrocarbon and typically includes<br>• hydrocarbons (including BTEX, PAH and naphthalene, phenanthrene and dibenzothiophene (NPD) compounds)<br>• metals, and<br>• production chemicals.<br>PFW is generally warmer and more saline than the receiving waters. The composition of the produced water discharge will vary over time as reservoir and production characteristics change. | Above the sea surface from the Crux platform† | During commissioning and operational phase – continuous discharge | Early operations – approximately 238 m$^3$/day<br>Late operations – up to 3,180 m$^3$/day |
| Wastewater and cooling water | Utility discharge streams including utility discharges from vessels such as domestic sewage, greywater, cooling water, reverse osmosis (RO) brine, bilge and deck drainage. | Crux platform (when manned)<br>Project vessels<br>Drilling rig | During all phases, with increased volumes during development drilling, installation, commissioning and decommissioning | Wastewater – approximately 14 m$^3$/day to 120 m$^3$/day per vessel<br><br>Cooling water – 5–10 m$^3$/day per vessel |
| Hydrotest water | Hydrotest water is used to assess the structural integrity of subsea infrastructure. Hydrotest water will be treated seawater and may contain biocide, dye (to aid in leak detection), oxygen scavenger, corrosion inhibitors and scale inhibitors. | Export pipeline – seabed at either the Crux platform or Prelude FLNG facility<br>Flexible riser – Prelude FLNG; Crux platform topsides and rigid riser:<br>Crux platform (either subsea or surface)<br>Future tiebacks – either at Crux platform or at tieback field location | One-off discharge for each component during commissioning phase, with the longest discharge duration approximately 44 hours (for the export pipeline) | Export pipeline – 47,500 m$^3$<br>Flexible riser – 100 m$^3$<br>Crux topsides/riser – 500 m$^3$<br>Future tiebacks – < 10,000 m$^3$ |
| Drilling fluids and cuttings | Drilling of the production wells will generate cuttings from the from the well. Drilling fluids (water-based and synthetic) will be used to cool and lubricate the drill bit, | Wells – from the MODU at the Crux platform location<br>Platform foundations (if required) – at the seabed at | During development drilling and installation – continuously during drilling of each well | Wells – < 5,000 m$^3$ per well (five wells in total for foundation development)<br>Platform foundations – |

| Discharge Stream | Description | Discharge Location | Project Stage and Duration | Indicative Volume* |
|---|---|---|---|---|
| | maintain overbalance, and remove cuttings from the well. Cuttings and drilling fluids are circulated to the drilling rig by a riser (lower sections). Cuttings will be processed onboard the drilling rig to recover drilling mud, and then discharged to the sea. Some residual drilling fluids will adhere to the drill cuttings.<br>The platform foundations (if required) may also be drilled. These may be drilled without a riser, and cuttings will be discharged at the seabed. Drilling fluids (or calcite or silicate based stabilising agents) may be used, if needed, to provide hole stability and will also be discharged at the seabed. | the Crux platform location<br>Future tiebacks – well location within the in-field development area | (approximately 34 days per well) | approximately < 2,500 $m^3$ per hole of cuttings^ |
| Minor accidental releases | The Crux platform, drilling rig and project vessels will have a range of chemicals and hydrocarbons stored in small quantities (e.g. cleaning products, hydraulic fluid etc.). Accidental spills of these may occur, potentially leading to unintentional discharge to the marine environment | Crux platform, project vessels and drilling rig | During all phases | Small (typically < 20 L) |

* The discharge volumes are based on engineering information available at the early stage of the project. While they are approximate and likely to be refined as the project concept definition progresses, they are considered appropriate to inform a robust assessment of potential impacts and risks at an OPP level of assessment. Further definition and assessment will be detailed in the activity-specific EPs.

† The discharge location of the PFW stream is yet to be finalised. The PFW handling process at the time of submitting this OPP involves discharging the PFW at the sea surface, however this may be subject to change (e.g. shallow subsurface discharge via a caisson). The modelling studies of PFW discharge include a sensitivity analysis of the effect of surface versus shallow subsea discharge (refer to **Appendix E**). This sensitivity analysis indicated there are not significant differences in the behaviour, mixing or fate of the PFW plume between surface and shallow subsea discharge.

^ The volume of drill fluids or calcite/silicate based stabilising agents that may be discharged to the seabed during drilling of the Crux platform foundations, should they be needed to maintain hole stability, is currently unknown. However, volumes are expected to be in the same order of magnitude as that discharged during the drilling of the foundation wells. The drill fluids used will be inherently low toxicity and SBM will not be used. The calcite or silicate based stabilising agents are inherently low toxicity and the precipitates inert. Calcite is a naturally occurring substance as calcium carbonate (i.e. limestone) while soluble silicates are derived from silica and soluble sodium and potassium compounds and ultimately revert to these forms when released to the environment (PQ Corporation n.d.).

### 8.4.8.2 Overview of Planned Discharge Modelling

Numerical modelling studies were commissioned by Shell to inform the assessment of impacts and risks from key planned liquid discharges, including:

- drilling fluids and cuttings (RPS 2018a)
- PFW (RPS 2018b), and
- hydrotest water (RPS 2018c).

The assumed constituents in the PFW are provided in **Table 8-40**. These were based on measured PFW concentrations for contaminants for which species protection concentration thresholds have been published by ANZECC & ARMCANZ. The measured values were derived from Shell's Auriga West-1 exploration well, which targeted hydrocarbons that may be produced by the Crux platform. While the PFW stream characteristics are based on a representative analogue for the Crux reservoir, review of the expected properties of the condensates within the additional fields that may be developed within the Crux in-field development area has shown that the key physico-chemical properties of these condensate are also comparable. Refer to (**Section 5.5.4** and **Section 8.4.9.2** (**Hydrocarbon Properties** heading) for further detail. The water content of the Crux field is also expected to be comparable to the additional fields within the Crux in-field development area, based on the most recent and reliable reservoir water sampling and analysis at Auriga West-1. Considering this, the PFW modelling results are considered to provide an appropriate representation of the nature and scale of the PFW stream that would be discharged from the development of the additional fields within the Crux in-field development area.

Hydrocarbons in the PFW stream can be considered as two discrete categories:

- partially soluble hydrocarbons – these are low molecular weight hydrocarbons that are partially soluble in water, such as light weight PAHs (e.g. benzene). These compounds are typically the most toxic hydrocarbons when introduced into the marine environment. These compounds are not significantly reduced by primary or secondary PFW treatment.
- insoluble hydrocarbons – these are non-polar hydrocarbons that are not significantly soluble in water. Most hydrocarbon compounds fall within this category. The PFW treatment system that will be used on Crux is intended to remove these compounds from the PFW stream, however very fine droplets of insoluble hydrocarbons may remain after treatment. These will be discharged with the PFW stream.

Table 8-40: Assumed Constituents of PFW Discharge

| Constituent | Assumed Concentration (mg/L[25]) |
|---|---|
| Benzene | 240 |
| Naphthalene, phenanthrene, dibenzothiophene (NPD) | 10.7 |
| Phenol | 0.757 |
| Cadmium (Cd) | $4.6 \times 10^{-3}$ |
| Chromium (III/IV) (Cr) | $2.48 \times 10^{-2}$ |
| Copper (Cu) | $9.2 \times 10^{-3}$ |
| Lead (Pb) | $4.6 \times 10^{-3}$ |
| Nickel (Ni) | $1.91 \times 10^{-2}$ |
| Zinc (Zn) | $2.94 \times 10^{-2}$ |

Reports documenting these modelling studies are provided in **Appendix D** to **Appendix F**. The planned discharges were modelled based on the context provided in **Section 5.7**,

[25] Concentrations of contaminants are often expressed in parts per million (ppm). The ppm and mg/L units are interchangeable if ppm is refering to a mass per unit volume.

with discharge locations, characteristics and volumes based on the current design of the Crux project (described in **Table 8-39**).

A custom composite regional hydrodynamic model for the project area, comprising both tidal (HYDROMAP) and mesoscale (HYCOM) models, was used to inform the modelling studies. The tidal, mesoscale and composite models were validated against oceanographic observations, including data collected within the project area, and showed strong agreement with oceanographic observations (RPS 2018e). This confirmed the model was suitable for predicting the fate of liquid discharges.

Each of the modelling studies used a stochastic modelling approach, where the release was repeatedly simulated using different metocean conditions. This process consisted of 100 deterministic model runs from three seasons – summer, winter, and a transitional season. The aggregated deterministic results (300 deterministic runs for each release scenario) constitute the stochastic data set, from which probabilities of contact above thresholds are determined. A stochastic modelling approach was used to inform the risk assessment[26]. This approach is inherently conservative, with the actual area affected by the planned discharges expected to be significantly smaller than the area identified by the stochastic modelling.

[26] A similar stochastic approach was applied to the modelling of worst-case hydrocarbon spills. Refer to **Section 8.4.9** and **Appendix G** for further information.

**Liquid Discharge and Hydrocarbon Spill Modelling**

Numerical models of discharges to the environment have been used to predict the fate of several liquid discharges and hydrocarbon spills in this OPP. These types of computer simulations are regularly used in assessing potential environmental impacts and risks (NOPSEMA 2018d). Modelling results are used to identify which environmental receptors may be impacted, and what the nature of contact with a discharge may be (e.g. the concentration of a discharge, the weathered state of a hydrocarbon etc.).

Two approaches to modelling studies have been implemented to inform the impact assessments of liquid discharges and hydrocarbon spills in this OPP:

- deterministic, and
- stochastic.

These modelling approaches are related and are described further below.

**Deterministic Modelling**

Deterministic numerical modelling can be used to predict the fate of a discrete liquid discharge or hydrocarbon spill. The outputs of a deterministic model are completely dependent on the inputs. If the inputs to a deterministic model are unchanged, the output will be exactly the same every time the model is run (i.e. there is no variability in the results given the same starting conditions).

If the input parameters are consistent with environmental conditions, and the model is a realistic simulation of environmental processes, outputs from the deterministic model will provide a realistic indication of the fate of the discharge. This makes deterministic models useful where there is a high degree of confidence in the initial conditions, but unreliable where the initial conditions may vary, such as dynamic meteorological and oceanographic conditions in the project area. Hence, Shell has also applied a stochastic modelling approach to modelling studies of liquid discharges and hydrocarbon spills.

**Stochastic Modelling**

Given modelling is used to predict the fate of a discharge in the environment, and the environmental conditions at the time of discharge are unknown and have a significant effect on the fate of a discharge, single deterministic model runs are not a reliable method to identify the environmental receptors that may be affected. This deficiency of deterministic modelling can be mitigated by using a stochastic modelling approach which incorporates uncertainty, providing a more reliable method to identify environmental receptors that may be affected. Stochastic oil spill modelling is created by overlaying a great number (often hundreds) of individual (i.e. deterministic), computer-simulated hypothetical releases (NOPSEMA, 2018d). Stochastic modelling is a common means of assessing the potential risks from liquid discharges such as PFW and hydrocarbon spills.

The modelling studies used to inform this OPP applied a stochastic modelling approach, which consisted of combining three hundred deterministic model runs for each of the release scenarios. These three hundred runs were aggregated to constitute the stochastic data set for each of the release scenarios. Variability in the metocean conditions was incorporated into the deterministic models by varying the time of the release within a ten year hindcast metocean model. This composite hydrodynamic model comprised mesoscale, wind and tidal currents and was validated against measured metocean conditions recorded in the Crux in-field development area.

Stochastic modelling has been used to identify environmental receptors that may be contacted by discharges or spills above a given dilution or threshold. Given the variability in the stochastic data sets, this process for identifying receptors is highly conservative; the number of receptors considered in the risk and impact assessments is significantly higher that would be affected by a single spill. The nature of exposure is based on the worst-case deterministic run that contacted each receptor.

Shell considers all environmental receptors identified as potentially being contacted, regardless of the likelihood. This approach is will identify more receptors than would be impacted by a given release, and hence it is environmentally conservative.

All models considered far-field effects, which is a suitable approach for estimating the fate of discharges in the environment given the nature and scale of the planned discharges. Near-field modelling was also undertaken for PFW and hydrotest discharges due to the nature of these discharges. Both types of model were run in these instances to simulate the different spatial scales at which processes influencing plume dilution operate.

An impact threshold was identified for each of the modelled discharge streams. These were based on relevant literature and accepted industry practices. These thresholds are discussed further in the sections below, and in the modelling technical appendices (**Appendix D** to **Appendix F**).

This approach was also applied to the assessment for significant unplanned releases of hydrocarbons; refer to **Section 8.4.9** for further information.

#### 8.4.8.3 Description and Evaluation of Impacts and Risks

**Physical Environment**

*Water Quality*

**Produced Formation Water**

PFW will be discharged from the Crux platform and will contain a range of potential residual contaminants, which is expected to include salts, hydrocarbons, metals and production chemicals. The likely PFW constituents and their concentrations was informed by Shell's Auriga West-1 exploration well, which targeted the Crux field, and Prelude operational experience. Concentrations for a range of these potential constituents used to inform the PFW modelling studies (RPS 2018b) are provided in **Appendix E**. Based on the threshold concentrations for these constituents, as defined in the ANZECC & ARMCANZ) (2000) guidelines, the required dilution factor to reach the 99% species protection level trigger for all constituents is < 1:500. Stochastic modelling results indicated that a 1:500 dilution (i.e. reaching 99% species protection level trigger) to occur within 999 m from the discharge point.

Maximum concentrations of PFW are expected to occur between 14–55 m water depth, which is the trapping depth of the PFW plume based on the modelling studies. This depth (and hence the vertical depth at which PFW dilutions occur) is highly dependent on the metocean conditions at the discharge location (RPS 2018b). Based on the modelling results, Shell expects most mixing of the PFW to occur in the top 100 m of the water column.

The PFW discharge is expected to be warmer and more saline than the receiving environment, with the discharge denser (i.e. negatively buoyant) than the receiving seawater.

Based on operational experience in the region (e.g. Prelude FLNG facility), potential contaminants such as naturally occurring radioactive materials (NORMs) and organic acids (e.g. acetic acid) are not expected to occur in quantities that may result in environmental impacts.

Modelling of PFW discharges was undertaken for both early phase (discharge rate of 287 $m^3$/day) and late phase (3,180 $m^3$/day) forecast maximum discharge rates using the methods outlined in **Section 8.4.8.2**. Near-field modelling results indicated the produced water plume would initially sink and undergo turbulent mixing.

Far-field stochastic modelling results indicated that high dilutions are expected to be achieved during the early operations phase (**Figure 8-22**), with 1:500, 1:2,000 and 1:4,000 dilutions expected to occur within 67 m, 356 m and 873 m, respectively, from the discharge location for all seasons (RPS 2018b). Stochastic modelling results for late phase operations indicated these dilutions would be achieved at increased distances from the discharge location due to the increased discharge rate (**Figure 8-23**). Maximum distances at which 1:500, 1:2,000 and 1:4,000 dilutions are expected are 999 m, 4,696 m and 7,814 m respectively. No named shoals or KEFs were predicted to be exposed to dilutions lower than 1:5,000.

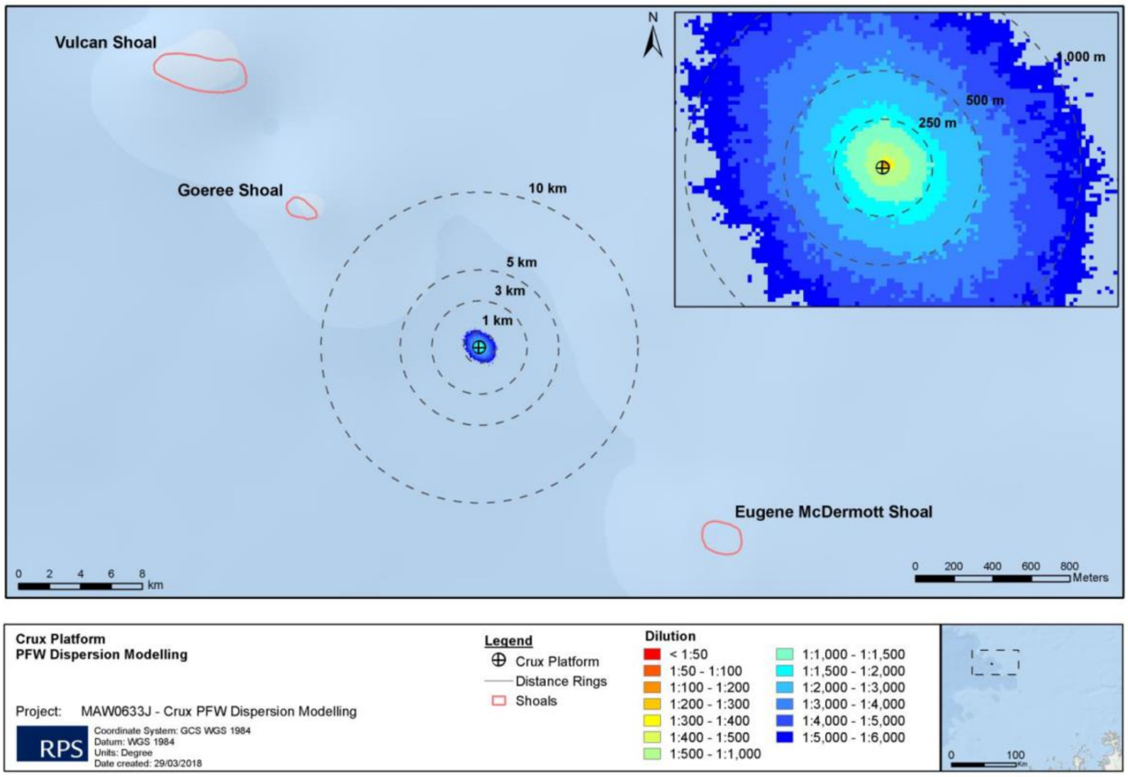



Figure 8-22: Predicted Annualised Minimum Dilutions for the Early Operations Phase Flow Rate of PFW

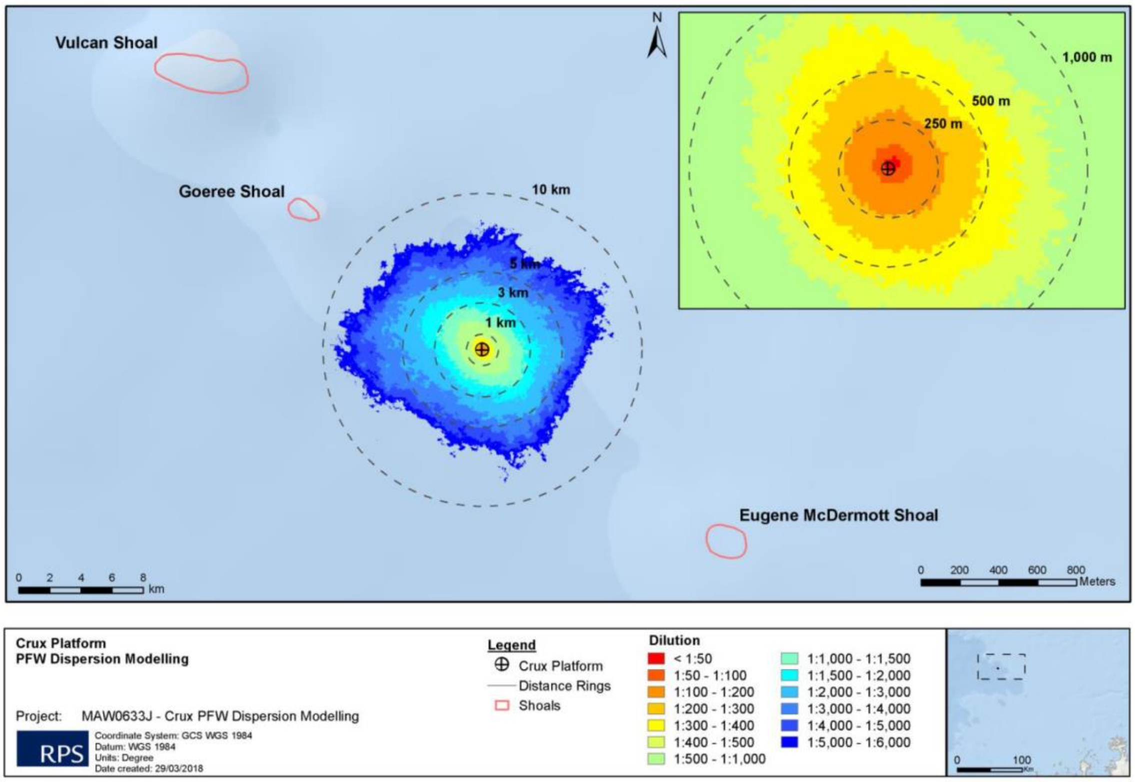



Figure 8-23: Predicted Annualised Minimum Dilutions for the Late Operations Phase Flow Rate of PFW

The salts within the PFW are expected to be similar in composition to the receiving seawater. Anions are expected to predominantly comprise sodium, calcium, magnesium and potassium. Cations are expected to comprise chloride, sulphate, bromide and bicarbonate. These ions (and their associated salts) are commonly found in seawater.

Hydrocarbons in the PFW will consist of both relatively low and high molecular weight compounds. Hydrocarbon solubility generally decreases with increasing molecular weight, and aromatic hydrocarbons also tend to have increased water solubility compared to non-aromatic hydrocarbons of equivalent molecular weight (Neff et al. 2011). As such, low molecular weight aromatic hydrocarbons are typically the most available in PFW. These compounds include BTEX, low-molecular weight PAHs, which include NPD and phenols. Low molecular weight hydrocarbons are of particular interest, as these tend to have the greatest potential for toxicity (Neff et al. 2011). Higher molecular weight compounds typically pose less environmental risk and are largely recovered during the production and PFW treatment processes onboard the Crux platform. Residual high molecular weight hydrocarbons will occur as very fine entrained oil droplets.

BTEX compounds are the most common hydrocarbon component of PFW. BTEX are highly volatile and do not persist in the environment; evaporation and dilution will rapidly reduce the concentration of BTEX in the receiving environment (Ekins et al. 2005, International Association of Oil and Gas Producers (IOGP) 2005. Neff et al. 2011). Other degradation processes such as biodegradation and photodegradation are expected to further reduce BTEX concentrations in the environment (Neff et al. 2000). BTEX is known to be toxic to marine organisms and has been shown to result in developmental defects (Fucik et al. 1995) but does not significantly bioaccumulate (Neff 2002). As such, potential impacts from the decrease in water quality due to BTEX will be localised to within a few hundred metres of the Crux platform during late phase operations.

PAHs are less volatile and soluble than BTEX and have greater potential to accumulate in the marine environment (Neff et al. 2011). PAHs can be broadly divided into two types; low molecular weight and those of high molecular weight. PAHs dissolved in PFW are predominantly low molecular weight and, while toxic, they are not mutagenic nor carcinogenic (although their metabolic by-products may be) (IOGP 2005). Higher molecular weight PAHs are rarely detected in treated PFW due to their low aqueous solubility. These compounds are primarily associated with dispersed oil droplets which are removed by the production process and produced water treatment system (Neff et al. 2011; Schmeichel 2017). PAHs are generally removed from the water column through volatilisation to the atmosphere upon reaching the sea surface, particularly the lower molecular weight fractions (Schmeichel 2017). PAHs can also degrade in the water column with half-lives ranging from less than a day to several months, with the more abundant and lower molecular weight compounds being more degradable (IOGP 2002).

The various trace metals that may be present in low concentrations in the PFW stream are generally in a low oxidative state and on release to the marine environment rapidly oxidise and precipitate into solid forms, which will be transported away from the discharge location while suspended in the water column (discussed further below in **Sediment Quality**). While concentrations of trace metals in PFW can be significantly greater than those in the marine environment, they are rapidly reduced through dilution and mixing processes, and other physicochemical reactions to levels that pose a low risk to the receiving environment (IOGP 2005).

A range of process chemicals may be introduced into Crux platform topside processing system and wells, and subsequently discharged to the sea as a component of the produced water. Some of the process chemicals will be in concentrations below that which are toxic to marine fauna, such as scale inhibitors, TEG and MEG, while others may be at concentrations that have potential to cause impact or contribute to the aquatic toxicity of the PFW, such as corrosion inhibitors and biocides (Neff 2002). The ecotoxicological impacts of process chemicals in PFW discharges was comprehensively investigated in a study by Henderson et al. (1999). The study tested 11 commonly used process chemicals (including biocides, corrosion inhibitors and demulsifiers) for their acute toxicity to marine bacterium, both directly in aqueous preparations and following their partitioning between oil and water phases. The study results indicated that toxicity of the PFW was not significantly altered by the presence of most process chemicals used in typical concentrations. A review of the study by Schmeichel (2017) notes that process chemicals make a small contribution to the overall acute toxicity profile of PFW discharges and even chemicals which are classified as highly toxic may not actually present an acute toxicity risk at dosages representing normal operating conditions. As such, production chemicals in the PFW discharge will not result in more than slight potential impacts to water quality. Further, TEG and MEG are ranked as E (lowest hazard) under the Offshore Chemical Notification Scheme Chemical Hazard and Risk Management (CHARM) non-CHARM products ranked list of notified chemicals and are considered readily biodegradable and non-bioaccumulative (Centre for Environment, Fisheries and Aquaculture Science 2019). The Oslo Paris Convention Commission also lists MEG as a substance considered to pose little or no risk to the environment.

When considering the small contribution of the process chemicals to the overall toxicity of PFW (as cited in Schmeichel 2017), it is expected the dilutions required to meet the 99% species protection levels trigger will not be significantly affected and, consequently, the spatial extent of the mixing zone is not expected to be substantially different. Noting there is a degree of uncertainty in any modelled prediction, Shell will develop an environmental monitoring program and adaptive management framework for PFW, to be informed by environmental monitoring and whole effluent toxicity (WET) testing once the Crux platform is operational (refer to **Section 9.3.7**).The decrease in water quality from potential contaminants in the treated PFW discharge stream may result in impacts to plankton. Research indicates that zooplankton exposed to low molecular weight hydrocarbons exhibit acute toxic effects (Almeda et al. 2013; Jiang et al. 2010) and developmental defects in fish (Fucik et al. 1995). In particular, PAHs are of concern due to their solubility, toxicity and relatively persistent compared to BTEX. The concentrations and durations of exposure required to induce these effects is unlikely to occur in the in-field development area due to the rapid dilution of PFW and the well mixed open ocean environment.

**Wastewater and Cooling Water**

Wastewater discharges from utilities onboard vessels and the Crux platform (when manned) such as sewage, greywater, bilge, RO brine, cooling water and deck drainage may result in increased levels of nutrients, chemicals and metals in the receiving environment. These discharges may also result in changes such as increased or decreased salinity, and changes to water temperature. Increased nutrients may enhance local planktonic productivity. Trace amounts of potential contaminants such as surfactants, hydrocarbons and metals may result in toxic effects on planktonic biota. Physical changes, such as changes to temperature (e.g. localised increase in temperature from cooling water discharges) or salinity (e.g. increased salinity from RO brine) will be localised to the discharge point and temporary. Given the relatively small volumes and transient nature of wastewater discharges, along with the well mixed offshore receiving environment, the potential for environmental impacts to water quality is slight.

**Hydrotest Water**

The discharge of hydrotest water associated with the project will result in a total of approximately 48,600 m$^3$ of treated seawater being released to the marine environment. The majority of this (approximately 47,500 m$^3$) will be discharged at the seabed from either the Crux or Prelude end of the export pipeline. The chemicals added to the treated seawater will result in the discharge of residual chemicals to the marine environment. These chemicals may include biocides, dyes, corrosion inhibitors and scale inhibitors; these residual chemicals may result in a temporary decrease in water quality in the water column affected by the discharge. This decrease in water quality may result in impacts to marine biota (discussed below in **Ecosystems, Communities and Habitats** and **Threatened Species and Ecological Communities**).

Shell commissioned RPS (2018c) to undertake a modelling study to better understand the potential fate of discharged hydrotest water in the environment; the report is provided as **Appendix F**. While the discharge location of the hydrotest water has not been determined and may be at either the Crux or Prelude ends of the export pipeline, the modelling study assumed the discharge to occur within the in-field development area. This is a "worst-case" discharge location due to the higher sensitivity of the receiving environment, due to:

- the closer proximity to benthic features such as shoals and banks that support relatively diverse biological communities, and
- the shallower benthic environment in general in the in-field development area, which supports more diverse benthic communities than the Prelude end of the export pipeline (Fugro 2017a).

The biocide concentration was the parameter modelled, as this component of the treated seawater has the greatest potential for environmental impacts. The modelling was based on the complete discharge of treated seawater from the export pipeline, with the concentration of biocide at the time of discharge assumed to be 500 ppm; this is a conservative assumption as the actual concentration is expected to be significantly lower than this. The modelling also assumed the biocide is not consumed in the environment (i.e. it does not get consumed as it reacts with material); which is an additional conservative assumption upon which the modelling results are based.

An impact threshold of 1 ppm of biocide was defined; it was assumed that concentrations below this threshold would not result in significant environmental impacts. This threshold is consistent with published acute toxicity test data for aquatic species for typical biocides that may be used. For example, the Wheatstone Project Offshore Facilities and Produced Formation Water Discharge Management Plan: Stage 1 (Chevron, 2015) identified an acute toxicity threshold of 1 ppm for Hydrosure, a representative biocide product. The Safety Data Sheet for Hydrosure O-3670R states the 96-hour $LC_{50}$[27] as 3.09 mg/L (3.09 ppm) for fish in marine waters, with a 48-hour $EC_{50}$[28] of 5.66 mg/L (5.66 ppm) for aquatic invertebrates (Champion Technologies, 2013). Sano et al (2005) assessed the potential toxicity effects of glutaraldehyde, another representative biocide, and reported a 24-hour $LC_{50}$ of 4.7 mg/L (4.7 ppm) for the aquatic invertebrate *Ceriodaphnia dubia*. Note that ecotoxicological studies are typically undertaken using constant doses for periods ranging from 24 to 96 hours under controlled conditions. This approach is in contrast to the natural environment, where the concentration and exposure durations can vary widely. For the purpose of this assessment, selection of an impact threshold of 1 ppm provides a conservative basis to evaluate the potential effects of biocide in the receiving environment.

Near-field stochastic modelling results indicated the velocity of the discharge plume will generate an initial turbulent mixing zone at the release location, followed by the marginally negatively buoyant plume sinking to the seabed and spreading in all directions from the discharge location. The stochastic modelling did not indicate that the 1 ppm threshold would be reached within the domain of the near-field model in any season. Far-field stochastic modelling indicated that the maximum and average distance from the discharge location that the 1 ppm threshold would be reached in any season was 5,727

[27] The $LC_{50}$ value is the leathal concentration required to kill 50% of a population in the given time

[28] The $EC_{50}$ is the median effective concentration. It is the concentation at which 50% immobilisation of the test organism is observed in the given time.

m and 5,263 m, respectively (**Figure 8-24**). Both the near-field and far-field stochastic results indicated that ambient currents provide the greatest influence on the advection and dilution of the treated seawater plume in the environment. Note that the stochastic modelling results did not indicate any shoals or banks would be contacted above impact thresholds (**Figure 8-24**).

The discharge of hydrotest water may result in the re-suspension of sediments in the immediate surrounds of the release location. Sediments at the Crux end of the export pipeline are characterised by sand and gravel fractions, while the Prelude end of the export pipeline is characterised by sands with a higher portion of muds. Discharge at either end of the export pipeline may initially re-suspend finer sediments, which will result in increased turbidity within the plume. Re-suspension will taper off as fine sediments become exhausted around the discharge point. Near-field modelling indicated the velocity of the discharge will slow upon exiting the export pipeline due to turbulent mixing, and hence the potential for sediment re-suspension is concentrated around the discharge location.

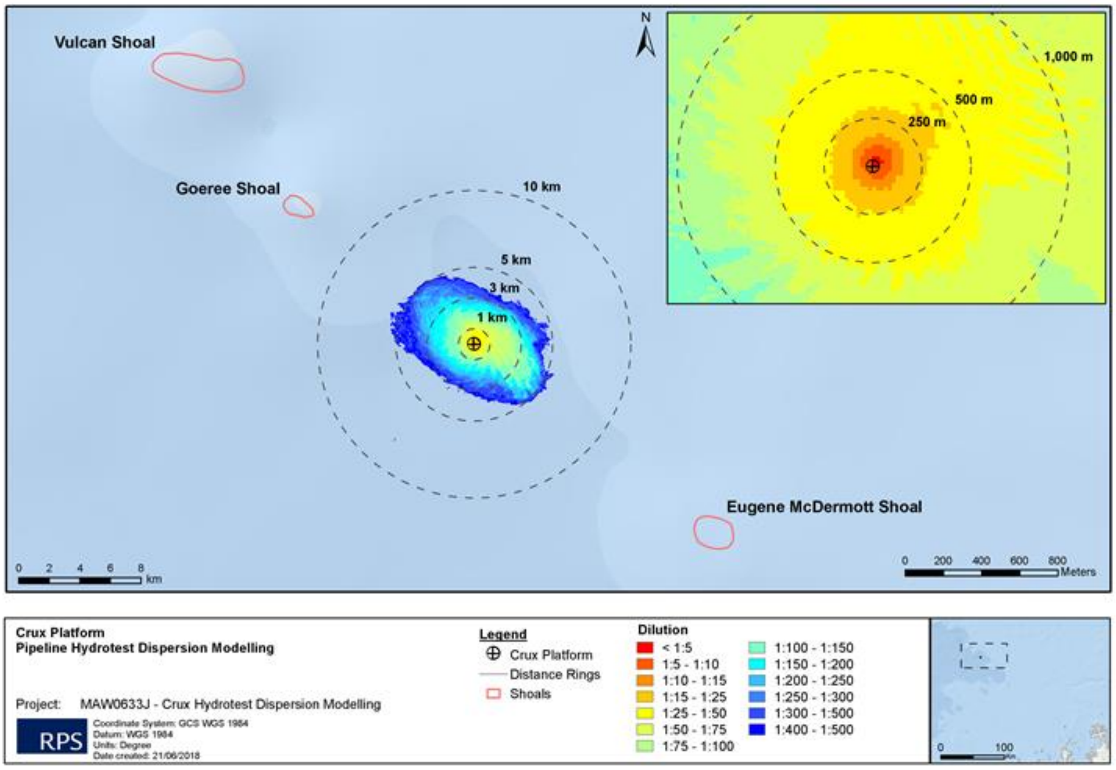



Figure 8-24: Predicted Annualised Dilutions of Hydrotest Water

### Drilling Fluids and Cuttings

The discharge of drill cuttings will impact the physical properties of the receiving marine environment. The offshore receiving environment typically has low turbidity (AECOM 2016), and the discharge of drill cuttings from the drilling rig will result in a temporary increase in turbidity and TSS. The nature of the change in turbidity is dependent on the characteristics of the cuttings, primarily size and density. The particle size distribution of cuttings will vary based on the geology of the formations being drilled, the characteristics of the drilling equipment, and the design of the well. Cuttings typically range from coarse gravel (> 32 mm) to silt (< 63 µm). Coarse particles will typically settle rapidly and have little potential to impact water quality (IOGP 2016). As cuttings particle size decreases, the settling velocity will typically decrease, and the ratio of residual drilling fluids to cutting size increases. This will result in a turbid plume that will decrease as the plume is diluted and the suspended particles are deposited (**Figure 8-25**; Continental Shelf Associates 2006). Results from the modelling of drill cuttings and fluids discharges for the Crux foundation wells indicated dilution is expected to occur rapidly due to the currents in the open ocean environment (RPS 2018a).

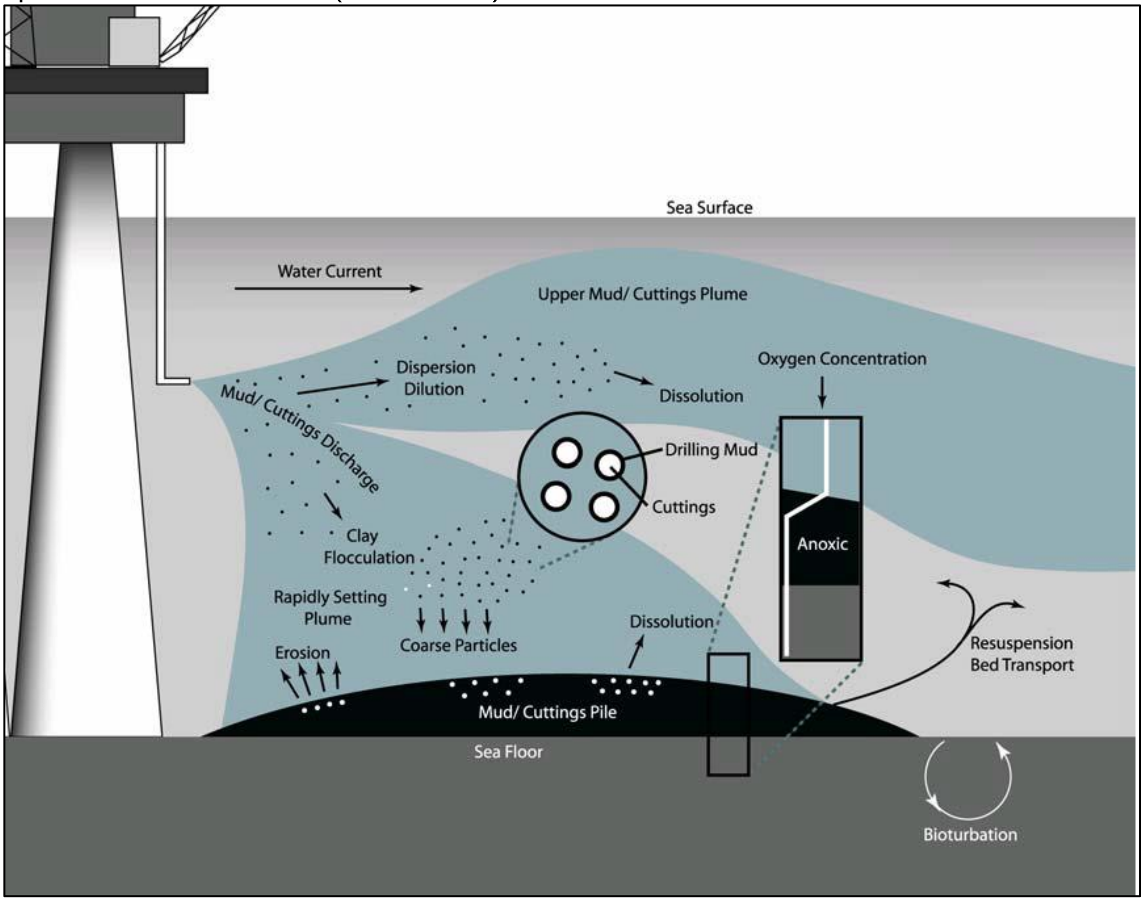



Figure 8-25: Generalised Schematic of the Fates of Drill Cuttings and Fluids Discharges

Dissolved components of the plume, particularly the salts and water-soluble drilling fluid organic additives, dilute rapidly by mixing in the water column. Most of the organic additives in water-based and synthetic-based muds are strongly adsorbed to inorganic cuttings particles and are deposited to the sediments rather than being available in the water column.

Studies by Smit et al. (2008) indicated that phytoplankton and filter-feeding zooplankton typically exhibit greater effects from suspended solids from drilling and suggested that these biota are less well-adapted to relatively high concentrations of suspended sediments than benthic biota. Smit et al. (2008) suggested that impacts to zooplankton were primarily the result of physical effects to filter-feeding and respiration organs, while impacts to phytoplankton were the result of reduced light levels. Concentrations at which impacts to phytoplankton are highly localised and unlikely to occur > 25 m from the discharge point (IOGP 2016; Smith et al. 2004). Studies of zooplankton indicated effects of drilling fluids and cuttings at concentrations > 100 mg/L are unlikely, based on 96-hr exposure duration experiments. Concentrations above > 100 mg/L for more than 96 hours during Crux project drilling activities would only occur in the immediate vicinity of the discharge location.

The foundation wells associated with the Crux platform location are not close to any sensitive environmental receptors; the nearest shoal (Goeree Shoal) lies approximately 13 km away. Impacts to water quality from the drilling of the foundation wells will not result in significant impacts to the banks and shoals within the Crux in-field development area. The absence of benthic primary producers in this environment and the relatively short duration of the discharge (i.e. only during drilling activities) limits the potential for decreased water quality to impact upon receptors such as plankton or benthic communities.

Tieback wells may occur in relatively close proximity to shoals and banks, with the closest possible discharge point approximately 2 km from the boundary of a shoal (i.e. 1 km buffer plus the MODU anchor chain; refer to **Will a One Kilometre Buffer Protect the Shoals?** for further information on the buffer). Impacts to water quality from the discharge of drilling fluids and cuttings typically occur within close proximity of the discharge point. As outlined above, very fine cuttings form a very small portion of the total amount of cuttings and fluids discharges as they tend to clump together to form larger particles that sink relatively quickly. There is the potential for the suspended sediment plume from these fine cuttings being advected over the shoals, however potential turbidity levels are expected to be very low. This reduction in light available is typically intermittent and brief (IOGP 2016). Increased turbidity from natural events (e.g. cyclones) occurs in the Timor Sea, and the biota of the shoals are adapted to short-duration increases in turbidity. A review by Erftemeijer et al. (2012) on the effects of turbidity and sedimentation on corals indicated that corals exposed to low levels of suspended sediments typically recovered rapidly. Given the levels of suspended sediments from drilling during the Crux project will approach natural levels within 2 km (RPS 2018a), no impacts to sensitive benthic habitats, such as corals, of the shoals within the Crux in-field development area are expected to occur.

**Minor Accidental Releases**

Given the relatively small volumes of chemicals that may be released because of accidental spills, the potential impacts to water quality will be localised and of short duration. Potential impacts will be a result of the nature of the spilled material, and may include:

- acute toxic effects to marine biota
- changes in water quality parameters (e.g. pH, salinity etc.), and
- changes in aesthetic quality (e.g. visual disturbance).

Any accidental releases within the project area will mix and dilute rapidly in the open ocean. Consequently, these potential impacts will be highly localised (i.e. to the immediate vicinity of the release location) and of short duration.

There are several scenarios that could potentially result in the release of large volumes of hydrocarbons (e.g. marine diesel, gas and condensate) to the marine environment. These are linked to major failures, and hence are beyond the scope of minor accidental releases. Refer to **Section 8.4.9** for the assessment of these unplanned hydrocarbon spills.

*Sediment Quality*

Liquid discharges with the potential to impact sediment quality include PFW, and drilling fluids and cuttings. Other liquid discharges were not considered to credibly result in impacts to sediments due to their transient nature (e.g. hydrotest discharge), low potential to harbour contaminants (e.g. wastewater and cooling water) or small volumes (e.g. minor accidental releases and utility discharges).

**Produced Formation Water**

The PFW discharge will contain a range of potential residual constituents. There are several processes by which these may become incorporated into the sediment, including:

- sedimentation of solids in the PFW
- dissolved contaminants forming precipitates, which settle to the seabed, and

- adsorption of contaminants onto natural suspended solids, which settle to the seabed.

The production process onboard the Crux platform will remove most solids from the produced water prior to discharge, and condensed water will not contain solids. Therefore, the mass of solids discharged in the PFW is expected to be very low. Under steady state operations, sand/fine volumes discharged overboard are anticipated to range between 0.01 $m^3$–2.3 $m^3$ over the cumulative life of the Crux field. Based on the Crux particle size distribution data, the fines volumes amount to only 5–10% of the produced solids after applying the selective perforation strategy and produced water treatment. The remaining solids discharged will be very fine in size, and hence will have low settling velocities. Given the water depth at the discharge location, the predicted behaviour of the plume, the surface discharge point, and the low settling velocities, residual solids will disperse widely and are unlikely to result in a decrease in sediment quality at the discharge location. The fines are also expected to be kaolinite (clay, silicate mineral), which is chemically inert and will not provide a pathway for dissolved materials in the PFW to precipitate and bind to. Therefore, the potential for sediment contamination is very limited.

Dissolved materials (particularly metals) in the PFW may form precipitates once released into the environment due to changes in pH and availability of reactants (e.g. oxygen, sulphide etc.). While the exact composition of the PFW cannot reasonably be characterised prior to commencing production (and may change character as reservoirs become depleted), metals commonly encountered at elevated levels in PFW include barium, iron and manganese (Neff et al. 2011). Solids formed by precipitation are initially very small and will have low settling velocities. As with solids, precipitates are unlikely to be deposited near the discharge location and will disperse widely; albeit at very low concentrations.

Some of the potential constituents in the PFW, such as metals and hydrocarbons, may become adsorbed onto the surface of suspended solids present in the receiving environment. Water quality studies in the project area have shown that natural suspended sediment levels are very low (AECOM 2016), refer to **Appendix A**.

This is consistent with the low observed rates of natural deposition in the region (Glenn 2004). The results of Glenn (2004) also showed that sediments locally derived from the water column are generally very fine (i.e. silt and clay sized particles). The low natural suspended sediment load indicates the potential for adsorption of potential contaminants is limited. Due to the small particle size, the potential for adsorbed contaminants to be deposited at the discharge location is low; particles with adsorbed contaminants are expected to be widely diluted and dispersed, resulting in no measurable impact to sediment quality in the region.

Each of the mechanisms discussed above by which contaminants in the PFW may be incorporated into sediments is considered to result in no more than a slight effect on sediment quality. This is consistent with monitoring results for other offshore facilities, which generally show that natural dispersion processes appear to control the concentrations of potential contaminants from PFW in sediments to slightly above background concentrations (Neff et al. 2011). The discharge of PFW is expected to be relatively low for the majority of the production period, before increasing significantly as reservoirs become depleted. Therefore, the period with the greatest potential for impact is concentrated at the end of field life.

**Drilling Fluids and Cuttings**

Drill cuttings will be discharged from the drilling rig after being treated by solids control equipment to reduce the concentration of residual drilling fluids. Recovered drilling fluids are returned to the drilling rig mud pit and recirculated. In the case of the initial foundation well and wells associated with future subsea tie backs, cuttings from the upper well sections may be discharged directly to the seabed or recovered using a riserless mud recovery systems. It is expected that, in the event that drill fluids may be required to mitigate against hole instability during the platform foundation drilling activity, fluids will be discharged directly to the seabed. The majority of drill cuttings and residual fluids will be deposited in the area around the discharge location and will form a cuttings pile. The accumulation of cuttings will physically modify the sediments by modifying the particle size distribution. Stochastic modelling results indicate the cuttings pile may reach a thickness of up to 374 mm for a single well (RPS 2018a), which will be largely comprised of coarse cuttings directly under the discharge location.

The five planned foundation wells at the Crux platform will result in deposition of cuttings at the base of the Crux platform. Sediments at this location will be considerably modified by the discharges of drilling fluids and cuttings, however modelling studies indicate impacts to sediment will decline with increasing distance from the wells. Stochastic modelling for the cumulative deposition of drilling fluids and cuttings indicated the maximum thickness would be up to 1,888 mm as the base of the platform, with cumulative cuttings from five wells reaching the 1 mm thickness threshold at a maximum distance of 658 m from the Crux platform location.

Cuttings from an individual tieback well are expected to become progressively finer with increasing distance from the well location, with the thickness of deposited cuttings expected to be ≤ 1 mm (considered to represent a low ecological threshold) within 318 m of the discharge location (single well) (RPS 2018a). Deposition ≥ 10 mm thickness (representative of a high ecological threshold) for a single tieback well was predicted to extend up to approximately 62 m from the release location and cover an area of approximately 7,000 $m^2$ (or 0.7 ha). Cuttings > 0.25 mm in diameter are predicted to typically be deposited within 250 m of the discharge location for a single tieback well (RPS 2018a).

The coarser sediments deposited directly under the discharge location are unlikely to be resuspended by currents and will gradually be buried by naturally deposited sediments over time. Finer sediments deposited further away may be reworked by currents and transported via saltation or as suspended sediments.

The deposition of the drill cuttings and fluids may lead to a decrease in sediment quality in the affected area. The stochastic modelling showed that for the foundation wells, in which five production wells will be drilled from a single location (**Section 0**), deposition was expected to be ≤ 1 mm (low ecological threshold) within approximately 658 m of the discharge location and ≥ 10 mm (high ecological threshold) within approximately 248 m (RPS 2018a). However, for a single well (i.e. for future subsea tie backs), deposition thicknesses of ≤ 1 mm and ≥ 10 mm were predicted to be within approximately 326 m and 68 m, respectively.

WBMs will be used where practicable; SBMs will be used where required to meet technical and safety requirements. WBMs will constitute most of drilling fluids discharged to the marine environment. Cuttings may contain potential contaminants derived from the geological formations from which they are generated; however, the potential for cuttings to be a source of contaminants is low compared to residual WBM and SBM drilling fluids. The residual WBMs may include potential contaminants such as metals (predominantly barium, a component of the commonly used weighting agent barium sulphate), as well as residual organic matter. Microbial degradation of residual organic matter can lead to depletion of oxygen in sediments within the cuttings pile, although this is unlikely to impact upon biota.

Cuttings with SBMs tend to clump together in large particles that settle rapidly to the seabed (Neff et al. 2000) and are more likely to be concentrated around the release location than cuttings with residual WBMs. SBMs may contain a range of synthetic hydrocarbons such as paraffins and olefins, which have low potential for toxicity and bioaccumulation, but may persist in the environment. Cuttings with residual SBMs are expected to have a higher concentration of residual organic matter compared to WBMs. The seabed affected by cuttings with residual SBM have greater potential for oxygen reduction via microbial degradation and associated changes to sediment chemistry (e.g. modified reduction/oxidation (redox) potential).Upon completion of a well, excess WBM may be discharged to the ocean from the drilling rig and pose little environmental risk or impact beyond a localised, temporary sediment plume. Excess SBMs will not be discharged to the ocean and may either be reused or disposed of onshore.

**Ecosystems, Communities and Habitats**

*Benthic Communities*

**Produced Formation Water**

Given the discharge of PFW is at the sea surface and is expected to mix rapidly upon release, benthic communities are not expected to be directly contacted by the PFW plume. Changes to sediment quality because of the discharge of PFW are expected to be slight, which may have consequent slight effects on benthic fauna. These slight impacts are expected to be concentrated around the Crux platform and will be significantly smaller than other sources of impact (e.g. physical disturbance during installation of the Crux platform, export pipeline and subsea integration system and discharge of drilling fluids and cuttings).

As outlined in the **Sediment Quality** discussion above, the residual fines discharged in the PFW stream are expected to be limited (< 2.3 $m^3$ over the cumulative life of the Crux field) and consist of kaolinite (clay). Kaolinite is chemically inert and, as such, residual dissolved materials in PFW stream will be unable to bind to the clay and lead to sediment contamination. Consequently, potential impacts to benthic communities are anticipated to be slight.

**Hydrotest Water**

The residual biocide in the hydrotest treated seawater has the potential to be acutely toxic to a range of marine biota associated with benthic habitats, including fish, molluscs, and echinoderms (Chevron Australia 2015). Other components of the treated seawater, such as dye, scale inhibitor and corrosion inhibitor are expected to be less toxic than the biocide (INPEX 2010; ConocoPhillips 2018). The biocides routinely used in the oil and gas industry do not bioaccumulate and are expected to be consumed by microorganisms (e.g. bacteria) once discharged to the marine environment.

Stochastic modelling (described above in **Section 8.4.8.2**) indicated the area which may be exposed to hydrotest water below the 1:500 dilution (i.e. dilution required to reach the 1 ppm impact threshold) in the in-field development area extends in all directions from the discharge location (**Figure 8-24**). The maximum distance from the release location recorded in the 300 model runs that comprised the stochastic results at which the 1:500 dilution was achieved was approximately 5.7 km (average of 5.3 km). Benthic habitat mapping indicated the area potentially affected consists of gravelly sands with burrowing macrofauna or no macrobiota (Fugro 2017a). While not modelled, the distance at which the 1:500 dilution could occur at the Prelude end of the export pipeline is expected to be similar based on the similar nature of the discharge and oceanographic setting. The benthic habitats at the Prelude end of the export pipeline are characterised by muddy sands with burrowing macrofauna or no macrobiota (Fugro 2017a).

The burrowing macrofaunal and no macrobiota habitats that may be impacted by the hydrotest water discharge, and associated fauna groups, are widely distributed in the region and are not considered to be of high conservation value. The discharge of hydrotest water will not physically modify benthic habitats (apart from potential localised scouring around the discharge location), although benthic biota associated with these habitats may experience acute toxic effects resulting in injury or mortality. Given the scale of disturbance and the near-seabed currents in the in-field development area, recovery from the effects of hydrotest discharge is expected to occur through natural recruitment.

Modelling results indicated that the hydrotest discharges above impact thresholds could not credibly reach any KEFs or shoals/banks, nor could it reach the shallower benthic communities associated with the outcropping in the north-eastern part of the in-field development area (**Figure 8-24**).

**Drilling Fluids and Cuttings**

The discharge of drill cuttings and residual fluids will impact upon benthic communities due to the potential physical and chemical changes to sediments (refer to **Sediment Quality** above). The deposition of cuttings has the potential to smother sessile benthic organisms, with effects predicted to occur at deposition thicknesses of greater than 6.5 mm (IOGP 2016). Sedimentation is an ongoing natural process, and benthic organisms exhibit adaptations to respond to increased sediment deposition. Natural sedimentation rates Northwest Australia were estimated by Glenn (2004) ranged from approximately 0.17 mm and 2.23 mm per year.

Stochastic modelling results for the five well foundation development drilling program indicated deposition of drilling cuttings and fluids was expected to be ≤ 1 mm and ≥ 10 mm within approximately 658 m and 248 m of the discharge location, respectively (RPS 2018a). For a single well the deposition thickness of ≤ 1 mm and ≥ 10 mm were predicted to be within approximately 326 m and 68 m, respectively. Benthic communities subject to deposition between 1 mm and 10 mm thickness are less likely to experience mortality but may experience sub-lethal impacts (IOGP 2016), such as impaired feeding due to clogging of filter feeding organs and increased energy expenditure from removing sediment from burrows. Recognising that sediment deposition from drill cuttings and fluids is in addition to natural processes, benthic communities subject to deposition of drill cuttings and fluids of < 1 mm thickness are unlikely to experience impacts from physical deposition of cuttings, as this thickness is consistent with natural sedimentary deposition rates.

Changes in sediment chemistry may impact upon benthic communities, particularly changes in oxygen demand from biodegradation of organic compounds in residual drilling fluids. Trannum et al. (2010) examined the effects of cuttings with residual WBMs and found a significant reduction in abundance and diversity of benthic infauna with increasing cuttings thickness compared to natural sediment and suggested that changes in sediment chemistry were a significant factor. Increased oxygen demand resulting from aerobic degradation of organic compounds in the WBM were suggested as a cause, along with fluxes in silicon and phosphorous (Trannum et al. 2010). The effects at low sediment thickness (< 10 mm) were much less apparent than relatively high rates of burial; these results are consistent with findings from other investigations of potential impacts of WBMs (Smit et al. 2006). The increased oxygen demand will diminish over time as organic material is consumed and will approach natural conditions.

The recovery of the area subject to deposition ≥ 10 mm thickness will potentially take many years, depending on natural sedimentary processes. Recovery may be linked to the deposition of relatively fine natural sediments on the coarse sediments in the cuttings pile to create suitable habitat. Studies of the recovery of benthic communities on visible cuttings piles (consistent with the area subject to drill cuttings and fluids deposition ≥ 10 mm) indicated considerable recovery within three years (particularly where deposition was thinner), however the benthic communities had not yet recovered to be similar to pre-discharge conditions or the surrounding unaffected seabed.

The benthic communities at the Crux platform comprise sparse epibenthic burrowing macrofauna on soft sediment substrates (Fugro 2017a). These are widely represented in the region and are not of high environmental value. Modelling studies (RPS 2018a) indicate these existing communities at the base of the Crux platform will be affected by the discharge of drill cuttings and fluids out to a range of approximately 326 m from the discharge point (e.g. some reduction in species diversity and abundance). High levels (> 10 mm) of burial will occur out to a radius of approximately 68 m; sessile benthic fauna within this range are expected to be completely removed.

Sensitive benthic habitats, such as the shoals within the Crux in-field development area or the continental slope demersal fish communities KEF will not be impacted by the discharge of drilling fluids and cuttings. The 1 km buffer around the shoals ensures that sediment deposition and suspended sediment plumes will not reach benthic habitats at the shoals (refer to the preceding section **Water Quality** and **Will a One Kilometre Buffer Protect the Shoals?** for further information). The distance between the Crux in-field development area and the continental slope demersal fish communities KEF (approximately 73 km from the Crux platform) ensures there will be no impacts to the environmental values of the KEF from drilling fluids and cuttings.

#### Threatened Species and Ecological Communities

*Key Fauna Species*

**Produced Formation Water**

Most threatened fauna species within the area predicted to be influenced by the PFW discharge are air breathing vertebrates, which are unlikely to be directly affected as their skin is relatively impermeable and breathe air. Hence, direct impacts are not considered credible. Indirect impacts, such as altered prey abundance or ingestion of bioaccumulated toxic compounds is considered to be of no effect given the localised area predicted to be impacted by PFW, the typically temporary or transitory presence of threatened fauna species, and the nature and scale of impacts to the marine ecosystem within the PFW discharge plume (i.e. minor impacts to plankton). Other fauna (e.g. pelagic and demersal fish) are expected to move away from areas if high concentrations of produced water, which will be localised to the vicinity of the release location. Hence potential impacts to these receptors are expected to be slight at worst. Anecdotal evidence from existing oil and gas platforms indicates this potential impact is unlikely, with well-developed marine communities, including mobile fauna such as fish, observed on platforms discharging PFW to the sea.

**Hydrotest Water**

Mobile benthic fauna such as fish and cephalopod molluscs may move away from the area affected by the plume, which may reduce potential impacts to these fauna. Potential impacts to fish assemblages are expected to be minor, and of no consequence to commercial fisheries in the region. Fauna of high conservation value (e.g. cetaceans, birds and marine reptiles) are typically concentrated in surface waters and will not be directly exposed to the hydrotest discharge plume.

**Drilling Fluids and Cuttings**

The discharge of drill cuttings and fluids will impact upon seabed habitat below the cuttings pile, particularly where the thickness of the deposition is ≥ 10 mm. This is not expected to result in impacts to key fauna species, as many key fauna are associated with surface waters and the water column (e.g. marine mammals, birds and marine reptiles). Given the depth of the in-field development area and the lack of benthic foraging habitat, marine turtles are not expected to be affected by the impacts to benthic habitats from the discharge of drill cuttings and fluids.

The localised, temporary decrease in water quality from the discharge of drill cuttings and fluids may temporarily displace pelagic marine fauna from the plume; this short-term, behavioural impact is considered to be negligible.

*Socio-economic and Cultural Environment*

Liquid discharges from the Crux project have little potential to impact upon socio-economic receptors (with the exception of low probability unplanned hydrocarbon spills; refer to **Section 8.4.9**). There is currently little exploitation of natural (e.g. hydrocarbons or minerals) or biological resources (e.g. fisheries or nature-based tourism) in the project area. While the discharge of PFW may lead to the introduction of contaminants with the potential for bioaccumulation, this is not expected to occur in organisms beyond the immediate area of the Crux platform (e.g. organisms living attached to the platform jacket); all unauthorised vessels, including fishing vessels, will be prohibited from the 500 m petroleum safety zone around the platform. Following cessation of discharges from the Crux platform (i.e. after operations have ceased), concentrations of potential contaminants in sediments are expected to decrease over time. The potential for sediment contaminants to bioaccumulate in exploited biological resources (such as fish) following decommissioning is considered to be very low given the nature of environment.

### 8.4.8.4 Risk and Impact Summary and Key Management Controls

Table 8-41: Liquid Discharges Evaluation of Impacts and Risks

| **Project Component/ Activity** | **Environmental Value/Sensitivity** | | | | **Evaluation – Planned** | | |
|---|---|---|---|---|---|---|---|
| | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Magnitude** | **Sensitivity** | **Residual Impact** |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from planned liquid discharges from the Crux project, including:<br>• PFW (including non-routine discharges of off-specification PFW)<br>• wastewater<br>• hydrotest water, and<br>• drilling fluids and cuttings. | X | X | X | | Minor | Medium | Minor |

| Evaluation – Unplanned Risks | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project Component/ Activity** | **Physical Environment** | **Threatened Species and Ecological Communities** | **Ecosystems, Communities and Habitats** | **Socio-economic and Cultural Environment** | **Significance** | **Likelihood** | **Residual Risk** |
| Unplanned risks resulting from accidental liquid discharges during the Crux project, including:<br>• minor accidental releases of chemicals/ hydrocarbons to the environment. | X | | X | | Moderate | Medium | Moderate |

***Key Management Controls***

*Utility Discharges*

All planned discharges from vessels will comply with relevant requirements of MARPOL 73/78, the *Navigation Act 2012*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and any subsequent Marine Orders requirements (as appropriate for vessel classification).

The Crux platform deck drainage shall be managed to reduce impacts on the environment.

Oily bilge water from machinery space drainage is treated to a maximum concentration of 15 ppm oil-in-water prior to discharge from vessels, as specified in MARPOL 73/78 (Annex I).

Offshore discharge of sewage from vessels will be in accordance with Marine Order 96.

Food wastes will be macerated to < 25 mm particle size whilst operational prior to discharge to sea, in accordance with Marine Order 95.

Containment around liquid hydrocarbon storage tanks will be installed on the Crux platform to reduce the potential for minor accidental releases of chemicals/hydrocarbons to the environment.

*Chemical Discharges*

For chemicals planned to be used in production and process (including in the subsea facilities and well) and for hydrotesting, and which will be discharged to the marine environment, will be selected in accordance with the Chemical Management Process for chemical selection and assessment of effects on the environment.

*Hydrotest Water Discharges (Crux export pipeline)*

An evaluation will be undertaken prior to hydrotesting of the Crux export pipeline to inform the selection of the discharge location of the pipeline hydrotest water (i.e. Crux versus Prelude end of the pipeline). The evaluation will include a comparison of environmental impacts between the two discharge locations, to determine which location has the lowest environmental impact. The evaluation will also consider safety and technical factors as part of the decision making process.

*Produced Water Discharges*

An environmental monitoring program and adaptive management framework will be developed for PFW. The monitoring program will include:

- continuous monitoring, whilst available, of PFW discharge volume (online flow meter) and dispersed oil-in-water (online oil-in-water analyser)
- chemical characterisation of PFW – WET testing will be completed when a suitably representative PFW sample of normal operations can be taken, and then on a risk-based approach thereafter
- additional monitoring as a result of trigger actions, and
- periodic environment monitoring within the in-field development area.

The oil-in-water concentration of PFW will be continuously monitored by an online analyser, while available, which will be fitted with an alarm that activates if the oil-in-water concentration is > 30 mg/L.

Calibration of the online analyser will be undertaken regularly during the initial early operations phase.

*Drilling Fluid and Mud Discharges*

No planned discharge of whole SBM will occur during development drilling.

| |
|---|
| When using SBM, the solids control equipment will reduce the residual base fluid on cuttings content prior to discharge overboard. Residual base fluid on cuttings will be less than 10% w/w averaged over all well sections using SBM.<br>If drilling for future tie-backs is proposed within 2 km of the shoals within the Crux in-field development area then additional modelling will be undertaken. The concept select for any future tie-backs will use the results of the modelling to inform selection, to achieve acceptable impacts.<br>Should new regionally relevant information become available that provides scientific evidence that 2 km is not a suitably conservative buffer to protect drill cuttings and fluid impacts on coral communities at the shoals as related to tie-backs, Shell will apply an adaptive management approach informed by further validation modelling. |

### 8.4.8.5 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the liquid discharges aspect of the Crux project are summarised in **Table 8-42**. The method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the environmental risks and impacts that may result from the liquid discharges aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the liquid discharges aspect of the Crux project is provided below.

Table 8-42: Acceptable Levels of Impacts and Risks from Liquid Discharges

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Physical environment | Water quality | No significant impacts to water quality during the Crux project. | Yes. Liquid discharges have the potential to result in reduced water quality at the discharge location, however discharges will dilute in the open ocean environment. Modelling studies indicate impacts to water quality are highly localised around the discharge location (being open offshore waters), which is consistent with industry monitoring studies. Shell will implement measures to reduce the potential for impacts to water quality from routine discharges, including PFW treatment systems and controls relating to the discharge of drilling fluids and cuttings. |
| | Sediment quality | No significant impacts to sediment quality during the Crux project. | Yes. The discharge of drilling fluids and cuttings and PFW may result in a decrease in sediment quality at drilling locations and the Crux platform. Modelling studies indicate impacts to sediment quality are highly localised around the discharge location (smooth, bare sandy seabed that is of low ecological value), which is consistent with industry monitoring studies. Shell will implement measures to reduce the potential for impacts to sediment quality from routine discharges, including PFW treatment systems and controls relating to the discharge of drilling fluids and cuttings. |

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Ecosystems, communities and habitats | Benthic communities | No significant impacts to benthic habitats and communities.<br>Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | Yes. The benthic communities (excluding shoals) within the Crux in-field development area that may be impacted by liquid discharges are broadly represented in the region and are not of high environmental value. The 1 km buffer around shoals within the Crux in-field development will protect these sensitive environmental features.<br>Tieback wells may be drilled in closer proximity to the outcropping reef feature. This feature is part of an extensive seabed ridge and surveys within the Crux in-field development area suggest it does not support highly diverse benthic communities, such as those characteristic of shoals and banks within the region. Should future tie-backs be proposed within 2 km of the outcropping reef feature, additional studies will be undertaken to further characterise the benthic habitats within the proposed disturbance area. |
| | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of cover of benthic habitats and communities at named banks or shoals as a result of indirect/offsite[29] impacts associated with the Crux project. | Yes. Most project activities will take place a considerable distance from the shoals. The Crux platform, which will be the location of PFW and drilling-related discharges, is approximately 13 km from the nearest shoal (Goeree Shoal).<br>Tieback wells may be drilled in closer proximity to banks and shoals. Liquid discharges from tieback wells are of relatively short duration and will not significantly impact upon the shoals due to the 1 km buffer that will be applied around these features. If future tie-backs are proposed within 2 km of the shoals within the Crux in-field development area, then additional studies will be undertaken to further characterise the benthic habitats within the proposed disturbance area. |
| | Key Ecological Features | No significant impacts to environmental values of KEFs. | Yes. The continental slope demersal fish communities KEF is not situated near any planned liquid discharge locations. Modelling studies indicate there is no potential for liquid discharges to impact upon the environmental values of this KEF. |

[29] As defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoE 2013a).

**Principles of ESD**

The risks and impacts from liquid discharges from the Crux project are consistent with the principles of ESD based on:

- the environmental resources within the project area are not expected to be significantly impacted, and
- the precautionary principle has been applied, and studies undertaken where knowledge gaps were identified.

**Matters of National Environmental Significance**

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates significant impacts[29] to threatened and migratory species will not credibly result from the liquid discharges aspect of the Crux project (note that unplanned spills are considered in **Section 8.4.9**).

Alignment of the Crux project with management plans, recovery plans and conservation advice for threatened and migratory fauna is provided in **Table 8-43**.

*Commonwealth Marine Environment*

Liquid discharges during the Crux project, such as hydrotest water, drilling fluid and cuttings and PFW, have the potential to impact upon the Commonwealth marine environment. In particular, sediment quality and water quality in the vicinity of liquid discharges may be degraded. As outlined in the description and evaluation of impacts and risks for liquid discharges (**Section 8.4.8.3**), the area influenced from routine operational discharges is expected to be limited to within 1 km of the liquid discharge locations. . However, these impacts are not considered to be significant when considered against the significant impact criteria for the Commonwealth marine environment (**Table 7-1**). In particular, the nature and scale of impacts and risks from liquid discharges is not considered sufficient to:

- modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth marine area results, or
- 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.

This assessment is further supported when considering that the receiving environment of smooth and bare sandy seabed and open offshore waters is widely represented and of generally low ecological value (in comparison to shoals/banks, reefs and KEFs).

While the potential for impacts from liquid discharges to the Commonwealth marine environment cannot be eliminated, Shell will manage liquid discharges to limit the spatial extent of such impacts. This is reflected in the acceptable levels of impacts to water and sediment quality:

- No measurable impacts to sediment quality or water quality in the region from liquid discharges during the Crux project.
- The area influenced by routine operational discharges is expected to be limited to within 1 km of the liquid discharge locations.
- Discharges at the Crux platform may result in impacts to water and sediment quality, both of which are components of the Commonwealth marine environment, within 1 km of the Crux platform or drilling locations. Impacts to water and sediment quality beyond this range are unacceptable.

- PFW discharges from the Crux platform will meet relevant ANZECC & ARMCANZ guidelines 95% species protection levels for sediment and water quality and/or be within natural variation or background concentration beyond the predicted mixing zone(s) under normal operations.

The acceptability of impacts are considered to be defined with reference to exceedance of the 95% species protection levels for marine sediments and water derived from either ANZECC & ARMCANZ (2000) or discharge-specific WET testing result using the ANZECC & ARMCANZ methodology. The ANZECC & ARMCANZ water quality guidelines are widely used throughout Australia and are routinely referred to in PFW monitoring programs.

The ANZECC & ARMCANZ water quality framework recommends monitoring programs be designed based on defining management aims and determining appropriate trigger values. Shell's management aims are to ensure that impacts from the discharge of PFW are within the acceptable level of impact. To identify suitable trigger values, Shell examined the ecosystem condition of the receiving waters around the Crux platform. The three ecosystem conditions recognised by ANZECC & ARMCANZ (2000) are:

- high conservation/ecological value systems – effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserved or in remote and/or inaccessible locations.
- slightly to moderately disturbed systems – ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained.
- highly disturbed systems – these are measurably degraded ecosystems of lower ecological value.

While remote, the Crux project area does not overlap any marine protected areas, and the presence of the Prelude FLNG at the western end of the export pipeline in an existing environmental disturbance. Prior to the discharge of PFW, the drilling of the foundation wells and construction of the Crux platform will disturb the environment. The lack of sensitive habitats within the area predicted to be affected by PFW discharge, along with the widespread distribution of such habitat in the region, indicates this area is not of high conservation value. Nor is the Crux project area a highly disturbed ecosystem. Hence, Shell concludes the ecosystem condition for the PFW discharge receiving environment is slightly to moderately disturbed. ANZECC & AMCANZ guidelines (2000) suggest that 95% species protection level triggers and direct toxicity assessment (DTA) (i.e. WET testing) be used for monitoring programs in slightly to moderately disturbed ecosystems. Shell's proposed controls and EPO are consistent with this approach.

Results from modelling studies suggest that the liquid discharges from the Crux project will not significantly impact upon the KEFs or shoals within or around the Crux project area.

Table 8-43: Summary of Alignment of the Risks and Impacts from Liquid Discharges from the Crux Project with Relevant Requirements for EPBC Threatened Fauna

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| Marine mammals | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Liquid discharges | The application of chemical selection process and proposed management of PFW discharges reduces the risk of persistent toxic pollutants being introduced to the marine environment.<br>An environmental monitoring program and adaptive management framework will be developed for PFW, to be informed by environmental monitoring and WET testing once the facility is operational. |
| | Conservation advice on *Balaenoptera borealis* (sei whale) (DoE 2015c) | Pollution (persistent toxic pollutants) | |
| | Conservation advice fin whale (*Balaenoptera physalus*) (DoE 2015d) | | |
| Marine reptiles | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Liquid discharges | |
| | Recovery plan for marine turtles in Australia (Commonwealth of Australia 2017b) | Chemical and terrestrial discharge | |
| Sharks and rays | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Liquid discharges | |
| | Conservation advice on *Rhincodon typus* (whale shark) (DoE 2015l) | Habitat disruption from mineral exploration, production and transportation | |
| Commonwealth marine environment | Significant impact guidelines for Commonwealth marine environment (**Table 7-1**) | Liquid discharges | The area influenced by routine operational discharges are expected to be limited to within 1 km of the liquid discharge locations. Impacts within this area are not considered to be significant in the context of the significant impact criteria for the Commonwealth marine environment given the nature and scale of the impacts and the characteristics of the local receiving environment (open offshore waters with smooth and bare sandy sediments). The impact assessment indicates the impacts and risks associated with the discharge of PFW will not result in a significant adverse impact on marine ecosystem functioning/integrity, social amenity or human health.<br>Shell has sought to reduce potential impacts through the selection of the PFW treatment system; the proposed PFW treatment is the best feasible option available for the Crux NNM platform. Shell's proposed EPO for PFW discharges |

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| | | | limits the spatial extent of impacts to the vicinity of the Crux platform and makes use of the ANZECC & ARMCANZ water quality guidelines (2000). |

**Relevant Requirements**

Management of the impacts and risks from liquid discharges associated with the Crux project are consistent with relevant legislative requirements, including:

- compliance with international maritime conventions, including:
  - MARPOL:
    - Annex I: regulations for the prevention of pollution by oil
    - Annex II: regulations for the control of pollution by noxious liquid substances in bulk
    - Annex III: regulations for the prevention of pollution by harmful substances carried by sea in packaged form, and
    - Annex IV: regulations for the prevention of pollution by sewage from ships
- compliance with Australian legislation and requirements, including:
  - *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*:
    - Marine Order 91 (Marine pollution prevention – oil)
    - Marine Order 93 (Marine pollution prevention – noxious liquid substances)
    - Marine Order 94 (Marine pollution prevention – packages harmful substances), and
    - Marine Order 96 (Marine pollution prevention – sewage).
- management of impacts and risks are consistent with policies, strategies, guidelines, conservation advice, and recovery plans for threatened species (**Table 8-43**)
- implementation of recognised industry standard practice, such as:
  - no discharge of whole SBMs
  - use of solids control equipment on the drilling rig, and
  - treatment of PFW to < 30 mg/L residual oil.

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

**Acceptability Summary**

The assessment of impacts and risks from liquid discharges determined the residual impact and risk ratings were all Minor or lower (**Table 8-41**). As outlined above, the acceptability of the impacts and risks from liquid discharges associated with the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

The residual impacts and risks are moderate. Shell considers residual impacts of moderate to be acceptable if (**Section 7**):

- all practicable measures have been identified commensurate with the risks and impacts
- internal context – the proposed controls and residual risk level are consistent with Shell policies, procedures and standards
- external context – consideration of the environment consequence and stakeholder expectations, and
- other requirements – the proposed controls and residual risk level are consistent with national and international standards, laws and policies.

The discussion above demonstrates that these requirements have been met in relation to the impacts and risk of liquid discharges for the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from liquid discharges associated with the Crux project to be acceptable.

#### 8.4.8.6 Environmental Performance Outcomes

**Physical and Biological Environment**

No measurable impacts to sediment quality or water quality in the region from liquid discharges during the Crux project.

PFW discharges from the Crux platform will meet relevant ANZECC & ARMCANZ guidelines 95% species protection levels for sediment and water quality and/or be within natural variation or background concentration beyond the predicted mixing zone(s) under normal operations.

Direct impacts to benthic habitats from the Crux project will be limited to < 0.1% of the total project area.

No mortality or injury of threatened and migratory MNES species as a result of liquid discharges during the Crux project.

Impacts from liquid discharges from the Crux project on the continental slope demersal fish communities KEF will be limited to <1% of the total area of the KEF.

No direct loss of coral communities (coral colony) at Goeree Shoal, Eugene McDermott Shoal and Vulcan Shoal will occur as a result of liquid discharges from the Crux project.

No direct loss of coral communities on the outcropping reef feature will occur as a result of the discharge of drill fluids and cuttings for future tie-back wells within the Crux in-field development area.

### 8.4.9 Unplanned Spills

#### 8.4.9.1 Project Context

The Crux project will involve the production and transport of large volumes of gas and condensate. Additionally, considerable volumes of hydrocarbons will be present onboard vessels for use as fuel. Several unplanned events (i.e. accidents or emergencies) resulting in the potential large-scale releases of these hydrocarbons were identified for the Crux project, including:

- a loss of well control (a well blowout) during drilling and operations
- a loss of process storage tank containment on the Crux platform
- a loss of subsea containment from the export pipeline, and
- a loss of fuel from a vessel.

A worst-case scenario resulting from each of these events has been considered in this environmental risk assessment. Each of these scenarios is discussed further below. Each of these scenarios can result in smaller spills than the worst-case credible spills discussed below. Smaller unplanned spill scenarios, such as incidental spills from vessels, are considered in **Section 8.4.8**; the potential consequences of these spills are much smaller than the large volumes hydrocarbon releases considered below.

**Loss of Well Control**

The Crux project involved drilling and completion of, and production from, a series of subsea wells. Shell engineering standards require a range of features which manage the risk of a loss of well control to very low levels. However, there is a possibility that a loss of well control may occur during drilling and operation of the Crux platform. While the likelihood is very small, a complete loss of well control (a well blowout) has the potential to release significant volumes of condensate into the environment. Such a release could result in significant environmental damage.

The likelihood and potential release volumes of a loss of well containment will change during different phases of the Crux project. Industry statistics from wells using similar controls that will be applied during development drilling of, and production from, the well within the scope of this OPP indicate the likelihood of a well blowout are:

- development drilling and completions – $2.5 \times 10^{-4}\ Q^{-0.3}$ per well, and
- production – $6.9 \times 10^{-5}\ Q^{-0.3}$ per well per year.

Where Q is the mass of spilled hydrocarbons in tonnes (Det Norske Veritas 2011).

These functions are shown in **Figure 8-26**, and are consistent with observed well blowout data observations in Australia and similar jurisdictions around the world. Most loss of well control incidents do not result in a worst-case well blowout scenario, and typically release relatively small masses of hydrocarbons. The likelihoods of a well blowout from development drilling and production are considerably lower than a loss of containment from an exploration well, as are the release masses (**Figure 8-26**); exploration wells will not be drilled during the Crux project.

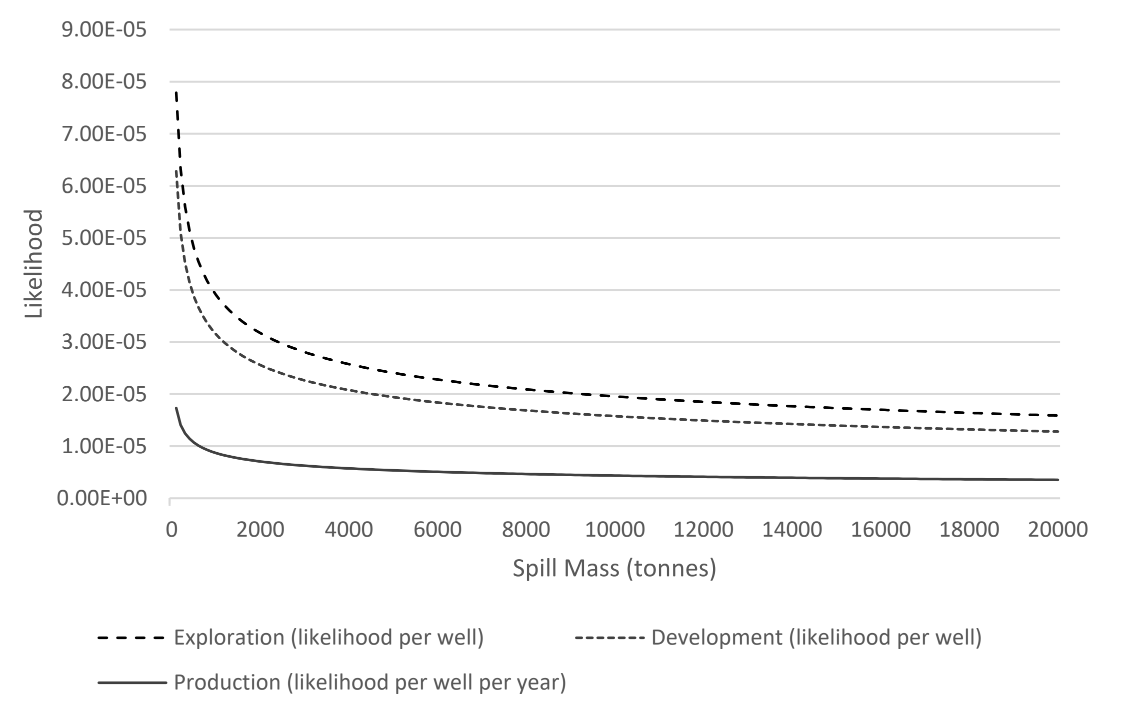



Figure 8-26: Estimated Likelihood and Mass of Well Blowouts for Exploration, Development and Production Wells (after Det Norske Veritas 2011)

Shell has extensive experience with safe and environmentally responsible drilling and reservoir engineering worldwide. Shell has developed a detailed understanding of the Crux field through historical seismic surveys and drilling. The offshore oil and gas industry has improved environmental performance since the Macondo and Montara catastrophes, and Australian regulations require that all environmental risks be managed to a level that is ALARP and acceptable. This is done through NOPSEMA's EP framework. All petroleum activities considered in this OPP will be undertaken under an accepted EP. All wells will be drilled and operated in accordance with an accepted WOMP in accordance with the OPGGS Act.

Shell has determined the worst-case credible spill scenario that could occur from the wells within the scope of this OPP. This scenario is a complete well blowout of a Crux production well during development drilling. This scenario consists of an 80-day uncontrolled release of 206,225 $m^3$ of condensate (2,578 $m^3$ per day). The duration is based on the credible worst-case time required to control the well (either by capping or drilling of a relief well) and the volume is based on the maximum credible rate of release derived from the proposed well design and reservoir characteristics. The release location is at the seabed at the Crux platform. While this scenario is very unlikely, using the worst-case credible spill as the basis for the risk assessment provides an environmentally conservative assessment of the potential impacts and risks posed by the Crux project. Shell commissioned numerical modelling to inform the risk assessment; refer to **Section 8.4.9.2** for further information on this worst-case credible spill scenario and associated modelling.

There is potential, albeit highly unlikely, that a well blowout could credibly occur from the surface blowout preventer or a dry tree on the Crux platform during the life of the project. In this scenario, condensate would be released to the sea surface. The expected volumes of condensate and duration of the uncontrolled release are not anticipated to be worse than the subsea well blowout scenario described above.

**Loss of Process Storage Tank Containment**

The Crux platform will process well fluids, before exporting the hydrocarbon fractions to the Prelude FLNG facility. The process equipment on the Crux platform will store considerable volumes of condensate, that may be released to the environment in the event of loss of containment from process infrastructure.

A significant loss of containment from process equipment is highly unlikely and represents a significant safety risk to personnel onboard the platform. The offshore oil and gas industry routinely implements safety by design to reduce the likelihood of a process loss of containment and reduce personnel exposure to significant risks (a key safety benefit of the NNM design of the Crux platform). This is reflected in industry statistics, which indicate a significant release of liquid hydrocarbons from offshore process equipment is very low, particularly for unmanned platforms (Det Norske Veritas 2011; IOGP 2010a).

Shell has determined the worst-case credible release from the Crux platform based on the preliminary design of the platform and associated processing equipment. This scenario consists of a short-term (< 1 hour) release of 88 $m^3$ of Crux condensate above the sea surface at the Crux platform location. This is the largest single vessel volume on the Crux platform at this time in the design process. As outlined above in **Loss of Well Control**, this is considered to provide an environmentally conservative assessment of potential impacts and risks from a loss of containment from process equipment. Shell commissioned numerical modelling to inform the risk assessment; refer to **Section 8.4.9.2** for further information on this worst-case credible spill scenario and associated modelling.

**Loss of Containment from Crux Export Pipeline**

The export pipeline will contain a significant volume of gas and condensate during production operations. A loss of containment from the pipeline may lead to the release of condensate to the marine environment. Pipeline loss of containment events can range from small 'pinhole' leaks (e.g. due to localised corrosion) through to complete rupture of the pipeline (e.g. due to significant mechanical impacts such as a drilling rig anchor being dragged over the export pipeline). Shell has extensive experience in the safe design and operation of subsea pipelines, and the oil and gas industry routinely implements a range of design standards and operational inspections to ensure pipeline integrity. This is reflected in the very low likelihoods of significant hydrocarbon releases from pipelines in jurisdictions similar to Australia (Det Norske Veritas 2011; IOGP 2010b).

Shell has determined the worst-case credible release from the export pipeline based on the preliminary design of the pipeline and the proximity of sensitive environmental receptors. This scenario consists of the short-term (< 6 hour) release of the entire contents (2,037 $m^3$ of Crux condensate) of the export pipeline from the point at which the pipeline is closest to a submerged shoal (Heyward Shoal) which was considered to represent the location which could potentially result in the worst-case environmental impact. This scenario accounts for a shut down time of 15 minutes at full flow rates, and time required for the release to equalise to outside pressure at 199 m at which the release was simulated. As outlined above in **Loss of Well Control**, this is considered to provide an environmentally conservative assessment of potential impacts and risks from a loss of containment from the export pipeline. Shell commissioned numerical modelling to inform the risk assessment; refer to **Section 8.4.9.2** for further information on this worst-case credible spill scenario and associated modelling.

**Loss of Fuel from Vessel**

The Crux project will require considerable use of a range of project vessels, from small platform support vessels to heavy lift and pipeline installation vessels. The frequency and duration of vessel activities will vary considerably depending on the project phase. Installation and decommissioning will be peak periods of vessel activity, and vessels will include heavy lift and construction vessels. The commissioning and operations phases (the longest phases of the Crux project) will involve relatively low vessel activity, comprised primarily of platform support vessels.

The nature and scale of the environmental risks and impacts from a loss of fuel from a vessel varies significantly based on the vessel type and activities. Vessels such as heavy lift and pipeline vessels typically store relatively large quantities of fuel. Often these types of vessels are fuelled using relatively heavy fuel oils, such as intermediate fuel oil (IFO). Smaller vessels, such as platform support vessels, typically store smaller quantities of fuel. Smaller vessels are typically fuelled using lighter fuel oils such as marine diesel, which are less persistent in the environment than heavier fuel oils.

Shell has determined the worst-case credible release from a loss of fuel from a vessel is a short-term (1 hour) release of 1,000 $m^3$ of IFO at the Crux end of the export pipeline. This scenario represents the loss of a significant volume of persistent fuel oil from a pipelay vessel. This scenario was identified as credibly arising from a collision with a large vessel (e.g. bulk carrier). Based on the shipping activity in the region and standard maritime practices, this scenario is considered extremely unlikely. As outlined above in **Loss of Well Control**, this worst-case credible spill scenario is considered to provide an environmentally conservative assessment of potential impacts and risks from a loss of containment from a loss of fuel from a vessel. Shell commissioned numerical modelling to inform the risk assessment; refer to **Section 8.4.9.2** for further information on this worst-case credible spill scenario and associated modelling.

### 8.4.9.2 Overview of Unplanned Spill Modelling

Numerical modelling studies were commissioned by Shell for the worst-case credible spill scenarios outlined above. The characteristics of each scenarios used in the modelling are provided in **Table 8-44**.

Table 8-44: Summary of Modelled Hydrocarbon Spill Scenarios

| Scenario | Location Name | Latitude | Longitude | Depth (m) | Hydrocarbon Type | Duration | Total Volume ($m^3$) |
|---|---|---|---|---|---|---|---|
| Loss of well control | Platform | 12° 57' 52.46" | 124° 26' 33.21" | 169 | Crux condensate | 80 days | 206,225 |
| Loss of process tank containment on Crux platform | Platform | 12° 57' 52.46" | 124° 26' 33.21" | Surface | Crux condensate | Instant | 88 |
| Loss of containment from export pipeline | Near Heywood Shoal – export pipeline | 13° 15' 29.00" | 123° 54' 39.00" | 199 | Crux condensate | < 6 hours | 2,037 |
| Loss of fuel from vessel | Platform | 12° 57' 52.46" | 124° 26' 33.21" | Surface | IFO-180 | 1 hour | 1,000 |

A similar approach was applied to the hydrocarbon spill modelling as was used for the liquid discharges modelling described in **Section 8.4.8.2** (refer to the blue box describing the approaches to deterministic and stochastic modelling). The same validated composite regional hydrodynamic model for the project area (RPS 2018e). The tidal, mesoscale and composite models were validated against oceanographic observations, including data collected within the project area, and showed strong agreement with oceanographic observations (RPS 2018e). This confirmed the model was suitable for predicting the fate of hydrocarbon spills.

Each of the four spill scenarios was modelled using a stochastic modelling approach, where the release was repeatedly simulated deterministic model using different metocean conditions. A total of 300 deterministic model runs were undertaken for each worst-case credible spill scenario (100 during summer, 100 during winter and 100 during transitional season). The aggregated deterministic results (300 deterministic runs for each release scenario) constitute the stochastic data set, from which probabilities of contact above thresholds are determined. Shell considers all environmental receptors identified as potentially being contacted, regardless of the likelihood. This will identify more receptors than would be impacted by a given release, and hence it is environmentally conservative.

A single representative deterministic run was selected from the stochastic set based on the maximum oil volume accumulated across all shoreline receptors. This deterministic run for each of four scenarios has been presented as a time-series compilation of figures. This time-series compilation of figures provides an indication of how hydrocarbons released from a single worst-case spill event may behave in the environment. The time-series figure compilations include floating, entrained, dissolved and accumulated hydrocarbons.

**Surface Well Blowout Scenario versus a Subsea Well Blowout Scenario**

For the loss of well control scenario, a subsea well blowout was modelled as it is considered to represent the worst-case scenario when compared to a surface well blowout on the Crux platform. The subsea well blowout scenario has a large spill extent as a result of most of the hydrocarbon released becoming entrained (majority) and dissolved within the water column and being transported large distances by ocean currents. The surface expression of hydrocarbons would be relatively localised to the release location. Refer to **Summary of Unplanned Spill Modelling Results** below for further discussion of the predicted spatial extent of the hydrocarbons released from a subsea well blowout.

In a surface well blowout scenario, the majority of the hydrocarbons would be expected to be expressed as floating oil, given the surface nature of the release. The floating hydrocarbon slick would be expected to evaporate and weather rapidly due to the high portion of volatile hydrocarbons. Approximately 78% of the surface hydrocarbons are expected to evaporate within the 24 hours of reaching the sea surface, with approximately 92% evaporating after several days (RPS 2018d). The rapid rate of evaporation reduces the potential for entrainment and dissolution of a proportion of them into the water column. Given this, it is expected that the extent of the entrained and dissolved hydrocarbons would be smaller and within that predicted for a subsea well blowout. While the surface expression of hydrocarbons would be greater, they are unlikely to extend beyond that predicted for the entrained and dissolved component of the subsea well blowout given their volatile nature.

The relatively high portion of floating hydrocarbons from a surface release compared to a subsea release may result in differences in the nature and scale of the environmental impacts and risks. Environmental receptors associated with the sea surface, such as seabirds and air-breathing marine fauna (e.g. cetaceans and marine turtles), may be more likely to come into contact with hydrocarbons. Conversely, receptors on the seabed or in the water column are less likely to be exposed to hydrocarbons. The assessment of the potential impacts and risks in **Section 8.4.9.3** considers the impacts of floating oil on receptors associated with the sea surface within the Crux in-field development area and Timor Sea region more broadly. Hence, despite the potential differences in nature and scale between a surface and subsea well releases, the impact assessment encompasses the credible impacts and risks that may arise from a worst-case surface well blowout release.

While there are some differences between the fate and expression of the hydrocarbons associated with a surface and subsea well blowout, as described above, the extent of the overall area that may be affected is expected to be greater for a subsea release scenario. Given the extensive nature of the area that may be affected by a subsea well blowout (as shown in **Figure 6-1**), no additional environmental values or sensitivities are likely to be affected by a surface well blowout. Therefore, the assessment of potential impacts and risks for a subsea well blowout is considered appropriate and representative of that associated with a surface well blowout scenario.

**Hydrocarbon Characteristics**

*Crux Condensate*

Crux condensate is relatively volatile (> 90% volatile hydrocarbons by mass), non-viscous hydrocarbon mixture. Soluble aromatic hydrocarbons contribute approximately 12.3% by mass of the whole condensate, with a large proportion (9.8%) in the C4–C10 range of hydrocarbons. These compounds will evaporate rapidly, reducing the potential for dissolution of a proportion of them into the water. The physical properties and boiling points of Crux condensate are presented in **Table 8-45** and **Table 8-46** respectively.

Table 8-45: Physical Properties of the Hydrocarbons used in the Modelling

| Physical Properties | Crux Condensate | IFO-180 |
|---|---|---|
| Density (kg/m$^3$) | 783.6 (at 15 °C) | 967.0 (at 25 °C) |
| API | 49.0 | 14.8 |
| Dynamic viscosity (cP) | 1.052 (at 20 °C) | 2,324 (at 15 °C) |
| Pour point (°C) | 9.0 | -10.0 |
| Hydrocarbon property category | Group I | Group IV |
| Hydrocarbon persistence classification | Non-persistent | Persistent (heavy) |

Table 8-46: Boiling-point Breakdown of the Hydrocarbons used in the Modelling

| Oil Type | Volatiles (%) | Semi-Volatiles (%) | Low Volatiles (%) | Residual (%) | Aromatics (%) |
|---|---|---|---|---|---|
| Boiling point (°C) | < 180<br>C4 to C10 | 180–265<br>C11 to C15 | 265–380<br>C16 to C20 | > 380<br>> C20 | Of whole oil<br>< 380 BP |
| | *Non-persistent* | | | *Persistent* | - |
| Crux condensate | 54.8 | 22.8 | 14.6 | 7.8 | 12.3 |
| IFO-180 | 1.0 | 14.4 | 20.8 | 63.8 | 5.9 |

While the additional fields that may be developed within the Crux in-field development area may not be directly connected to the Crux Field, they form part of the same Jurassic – Cretaceous East Browse Basin petroleum system and therefore are anticipated to have very similar hydrocarbon fluid properties. Furthermore, review of the expected properties of the condensates within some of the additional fields that may be developed within the Crux in-field development area has shown that the key physico-chemical properties (i.e. density and API gravity) of these condensates are comparable (refer to **Section 5.5.4**). The condensates are Group I oils (non-persistent) and similar in composition in terms of the volatile and residual components. The properties of the fluids within the additional fields must also be similar to Prelude reservoir fluid in order to meet the Prelude FLNG facility tolerances for processing, such that only condensates and oil (20 – 30 API gravity) can be processed on the Prelude FLNG facility. Given this, and the comparability of the physico-chemical properties of the condensates with the additional fields, the behaviour, weathering and fate of the hydrocarbons are expected to be similar. There are also expected to be no significant differences in terms of key inputs and parameters that underpin the spill modelling. Therefore, the modelling results for the Crux condensate spill scenarios are considered to provide an appropriate representation of the nature and scale of equivalent releases of condensate from the additional fields that may be developed within the Crux in-field development area. No new environmental values/sensitivities are anticipated to be affected should these condensates be released from the worst-case credible spill scenarios identified for the Crux project (**Table 8-44**), and the impacts and risks assessed for the Crux condensate are considered representative.

*Intermediate Fuel Oil*

IFO-180 has a high density (967 kg/m$^3$) and a high viscosity (2,324 cP), with a low portion of volatile component (**Table 8-45** and **Table 8-46**). Once released to the environment, most of the oil will spread and form a surface slick, with the small portion of volatile components evaporating.

Given the low viscosity of IFO, it is unlikely to become entrained under most wind and wave conditions (RPS 2018d). IFO-180 can form stable water-in-oil emulsions (also referred to as “chocolate mousses”) in which seawater droplets become suspended into the oil matrix (Fingas and Fieldhouse 2004). The formation of emulsions requires physical mixing (i.e. wave action), with the stability of the emulsion influenced by the properties of the IFO (which will change as the oil weathers). Emulsions are expected to become less stable over time as the water content reduces. Emulsification will affect the spreading and weathering of the oil and increase the volume of oily material and may the affect natural degradation rate (Fingas and Fieldhouse 2004).

The IFO will continue to degrade in the environment through weathering processes and microbial action. Residual oil may remain as floating oil, form tarballs, and become deposited to the seabed if subject to high suspended sediment loads (such as those observed in nearshore environment) (International Tanker Owners Pollution Federation 2011a). High suspended sediment loads and therefore sedimentation of oil is not expected in the offshore marine environment.

**Hydrocarbon Impact Thresholds**

Spilled hydrocarbons can exist as a range of fates, or phases, in the marine environment. These are floating, entrained, dissolved and accumulated (i.e. stranded onshore) hydrocarbons. Each of these fates, or phases, can interact with the environment in diverse ways due to different pathways to receptors and impact mechanisms.

A series of impact thresholds for floating, entrained, dissolved and accumulated hydrocarbons were determined. These thresholds were applied to the hydrocarbon spill modelling studies and used to inform the assessment of potential impacts and risks. Three thresholds were applied to each fate, or phase, (low exposure, moderate exposure and high exposure); these are described in **Table 8-47** (RPS 2018d).

Table 8-47: Summary of the Zones of Exposure and Thresholds

| Exposure Zone | Threshold | Justification |
|---|---|---|
| *Floating Hydrocarbon Threshold* | | |
| Exposure zone<br>Low exposure | 1 g/m$^2$ | The 1 g/m$^2$ threshold represents the practical limit of observing hydrocarbon sheens in the marine environment and therefore has been used to define the outer boundary of the low |

| Exposure Zone | Threshold | Justification |
|---|---|---|
| (1 g/m$^2$–10 g/m$^2$) | | exposure zone. This threshold is considered below levels which would cause environmental harm and is more indicative of the areas perceived to be affected due to its visibility on the sea-surface.<br>This exposure zone is not considered to be of significant biological impact but may be visible to the human eye. This exposure zone represents the area contacted by the spill and defines the conservative outer boundary of the area of influence from a hydrocarbon spill. |
| Adverse exposure zone<br>Moderate exposure<br>(10 g/m$^2$–25 g/m$^2$) | 10 g/m$^2$ | Ecological impact has been estimated to occur at 10 g/m$^2$ as this level of oiling has been observed to mortally impact birds and other wildlife associated with the water surface (French et al. 1996; French 2000).<br>The 10 g/m$^2$ threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment. |
| Adverse exposure zone<br>High exposure<br>(> 25 g/m$^2$) | 25 g/m$^2$ | The 25 g/m$^2$ threshold is above the minimum threshold observed to cause ecological impact. Studies have indicated that a concentration of surface oil 25 g/m$^2$ or greater would be harmful for the majority of birds that contact the hydrocarbon at this concentration (Koops et al. 2004; Scholten et al. 1996).<br>Exposure above this threshold is used to define the high exposure zone. |
| *Shoreline Hydrocarbon Threshold* | | |
| Exposure zone<br>Low exposure<br>(10 g/m$^2$–100 g/m$^2$) | 10 g/m$^2$ | In previous risk assessment studies by French-McCay et al. (McCay et al. 2005a, 2005b), a threshold of 1 g/m$^2$ was used to assess the potential for shoreline contact (by oil stranding on shorelines/beaches). It is a conservative threshold used to define regions of socio-economic impact, such as the need for shore clean-up on man-made concrete/stone walls or on amenity beaches. A less conservative threshold of 10 g/m$^2$ has been defined as the zone of potential 'low' exposure. This exposure zone represents the area visibly contacted by the spill and defines the outer boundary of the area of influence from a hydrocarbon spill. |
| Adverse exposure zone<br>Moderate exposure<br>(100 g/m$^2$–1,000 g/m$^2$) | 100 g/m$^2$ | French *et al.* (1996) and French-McCay (2009) have defined an oil exposure threshold of 100 g/m$^2$ for shorebirds and wildlife (furbearing aquatic mammals and marine reptiles) on or along the shore, which is based on studies for sub-lethal and lethal impacts. The 100 g/m$^2$ threshold has been used in previous environmental risk assessment studies (French et al. 2011; French-McCay 2004; French-McCay 2003; French-McCay et al. 2012; National Oceanic and Atmospheric Administration 2013). This threshold is also recommended in AMSA's foreshore assessment guide as the acceptable minimum thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone (AMSA 2015). Thresholds of 100 g/m$^2$ and 1,000 g/m$^2$ will define the zones of potential 'moderate' and 'high' exposure on shorelines, respectively. Contact within these exposure zones may result in impacts to the marine environment. |
| Adverse exposure zone<br>High exposure<br>(> 1,000 g/m$^2$) | 1,000 g/m$^2$ | |
| *Entrained Hydrocarbon Threshold* | | |
| Exposure zone<br>Low exposure<br>(10 parts per billion (ppb)–100 ppb) | 10 ppb | The 10 ppb threshold represents the 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 |

| Exposure Zone | Threshold | Justification |
|---|---|---|
| | | the entrained plumes, or when entrained hydrocarbons adhere to organisms or is trapped against a shoreline for periods of several days or more.<br>This exposure zone is not considered to be of significant biological impact. This exposure zone represents the area contacted by the spill and conservatively defines the outer boundary of the area of influence from a hydrocarbon spill. |
| Adverse exposure zone<br>Moderate exposure<br>(100 ppb–500 ppb) | 100 ppb | The 100 ppb threshold is considered conservative in terms of potential for toxic effects leading to mortality for sensitive mature individuals and early life stages of species. This threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations.<br>The 100 ppb threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment. |
| Adverse exposure zone<br>High exposure<br>(> 500 ppb) | 500 ppb | The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality for more tolerant species or habitats. This threshold has been defined to indicate a potential zone of acute exposure, which is more meaningful over shorter exposure durations.<br>The 500 ppb threshold has been selected to define the high exposure zone. |
| *Dissolved Aromatic Hydrocarbon Threshold* | | |
| Exposure zone<br>Low exposure<br>(6 ppb–50 ppb) | 6 ppb | The threshold value for species toxicity in the water column is based on global data from French *et al.* (1999) and French-McCay (2003, 2002), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour $LC_{50}$) under different environmental conditions varied from 6 ppb–400 ppb, with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Based on scientific literature, a minimum threshold of 6 ppb used to define the low exposure zones (Clark 1984; Engelhardt 1983; Geraci and St Aubin 1988; Jenssen 1994; Tsvetnenko 1998).<br>This exposure zone is not considered to be of significant biological impact. This exposure zone represents the area contacted by the spill and conservatively defines the outer boundary of the area of influence from a hydrocarbon spill. |
| Adverse exposure zone<br>Moderate exposure<br>(50 ppb–400 ppb) | 50 ppb | A conservative threshold of 50 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour $LC_{50}$ of 50 ppb could serve as an acute lethal threshold to 5% of biota.<br>The 50 ppb threshold has been selected to define the moderate exposure zone. Contact within this exposure zone may result in impacts to the marine environment. |
| Adverse exposure zone<br>High exposure<br>(> 400 ppb) | 400 ppb | A conservative threshold of 400 ppb was chosen as it is more likely to be indicative of potentially harmful exposure to fixed habitats over short exposure durations (French-McCay 2002). French-McCay (2002) indicates that an average 96-hour $LC_{50}$ of 400 ppb could serve as an acute lethal threshold to 50% of biota.<br>The 400 ppb threshold has been selected to define the high exposure zone. |

**Summary of Unplanned Spill Modelling Results**

*Loss of Well Control*

The worst-case deterministic run, determined to be the deterministic model run from the stochastic set with the greatest volume of hydrocarbons accumulating on shorelines, is shown in **Figure 8-27**. This deterministic run resulted in approximately 9.3 $m^3$ of hydrocarbon accumulation on the shoreline within and around the Djukbinj National Park in the NT.

This worst-case deterministic run indicated that hydrocarbons on the sea surface mainly drifted southwest of the release location. The potential floating oil exposure zones (low threshold) was limited to within 15 km of the release location, with the moderate and high thresholds not exceeded. The entrained oil and dissolved aromatic hydrocarbons were shown to move east and northeast of the release location. Low, moderate and high entrained hydrocarbons were observed up to 1,155 km, 1,048 km and 890 km, respectively, from the release location. Low, moderate and high dissolved aromatic hydrocarbons were observed up to 1,071 km, 597 km and 364 km, respectively, from the release location.

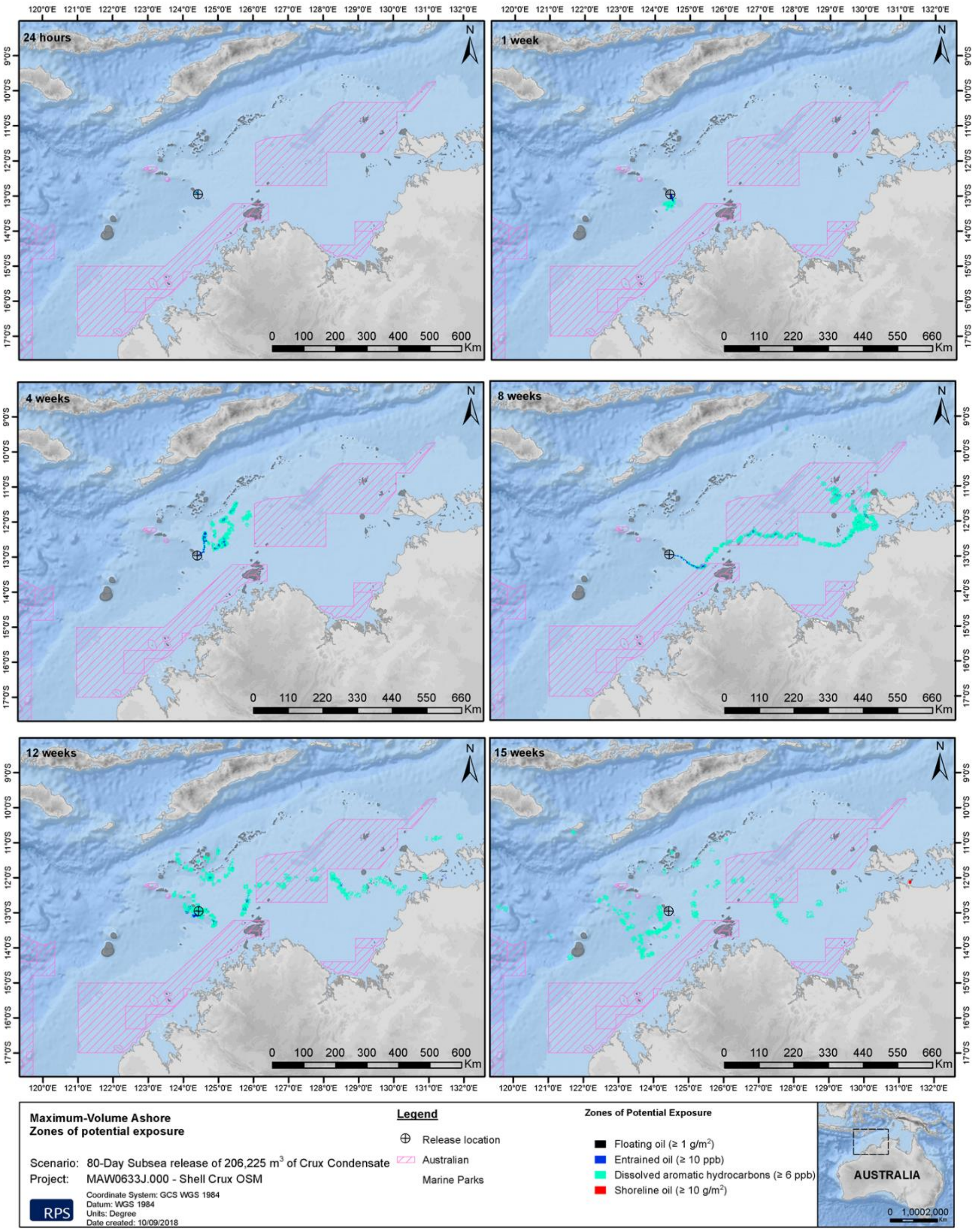



Figure 8-27: Time-varying Areal Extent of Potential Exposure at Floating, Entrained, Dissolved Hydrocarbon and Shoreline Hydrocarbon Low Exposure Threshold Concentrations Resulting from an 80-day Subsurface Release of Crux Condensate at a Development Well

Key results from the stochastic modelling studies for a worst-case loss of well control showed:

- floating hydrocarbons (**Figure 8-28**) were relatively localised to the release location due to the seabed release and the resulting entrainment of the condensate as very fine drops with low rising velocity. Modelling results indicated floating hydrocarbons would only occur above the low exposure threshold; no exceedance of the moderate or high floating hydrocarbon thresholds were predicted. The maximum distance to the outer extent of the low floating oil threshold is predicted to vary between seasons, extending to within 577 km, 387 km and 93 km during transitional, summer and winter conditions, respectively. Floating oil concentrations above the moderate threshold occurred only during the transitional season. The high floating oil threshold was not exceeded during any season.
- the potential for shoreline accumulation is very low, with potential shoreline accumulation predicted to occur at isolated location along the NT coastline during the summer season.
- entrained hydrocarbons (**Figure 8-28**, **Figure 8-29** and **Figure 8-30**) were predicted to extend in all directions. The maximum distance to the outer extent of the low entrained oil threshold is predicted to vary between seasons, extending up to 3,292 km, 2,589 km and 2,170 km during winter, transitional and summer conditions, respectively. The maximum extent is forecast to be slightly reduced for the moderate (100 ppb) and high (≥ 500 ppb) thresholds for all the seasons. Most of the spilled liquid hydrocarbons from a worst-case loss of well control will exist in the entrained phase.
- dissolved hydrocarbons (**Figure 8-28**, **Figure 8-29** and **Figure 8-30**) were predicted to follow a similar distribution to entrained hydrocarbons and extend in all directions. The maximum distance to the outer extent of the dissolved aromatic hydrocarbon low threshold (6 ppb) is predicted to vary between seasons, extending up to 3,280 km, 2,364 km and 1,764 km during winter, transitional and summer conditions, respectively. The maximum extent is forecast to be slightly reduced for the moderate (50 ppb) and high (≥ 400 ppb) thresholds for all the seasons.
- the loss of well control scenario will generate a plume of buoyant gas and condensate, which will rise rapidly through the water column (RPS 2018d). The resulting turbulent mixing of the gas and condensate with the water is predicted to entrain liquid hydrocarbons in the water column. Modelling results indicated these liquid hydrocarbon drops will be very small (< 30 µm) and will rise very slowly towards the sea surface (approximately 4.3 m per day). The droplets are expected to remain entrained in near-surface waters due to wind and wave action, although may form thin floating slicks under sufficiently calm conditions (RPS 2018d).
- the metocean conditions significantly affected the distribution of entrained and dissolved hydrocarbons. The strong mesoscale flow to the south-west during winter months associated with the ITF moved the majority of dissolved and entrained hydrocarbons in this direction for released during this season. The weakening of the ITF during transitional and summer months lead to increased probabilities of entrained and dissolved hydrocarbons moving east from the release location.

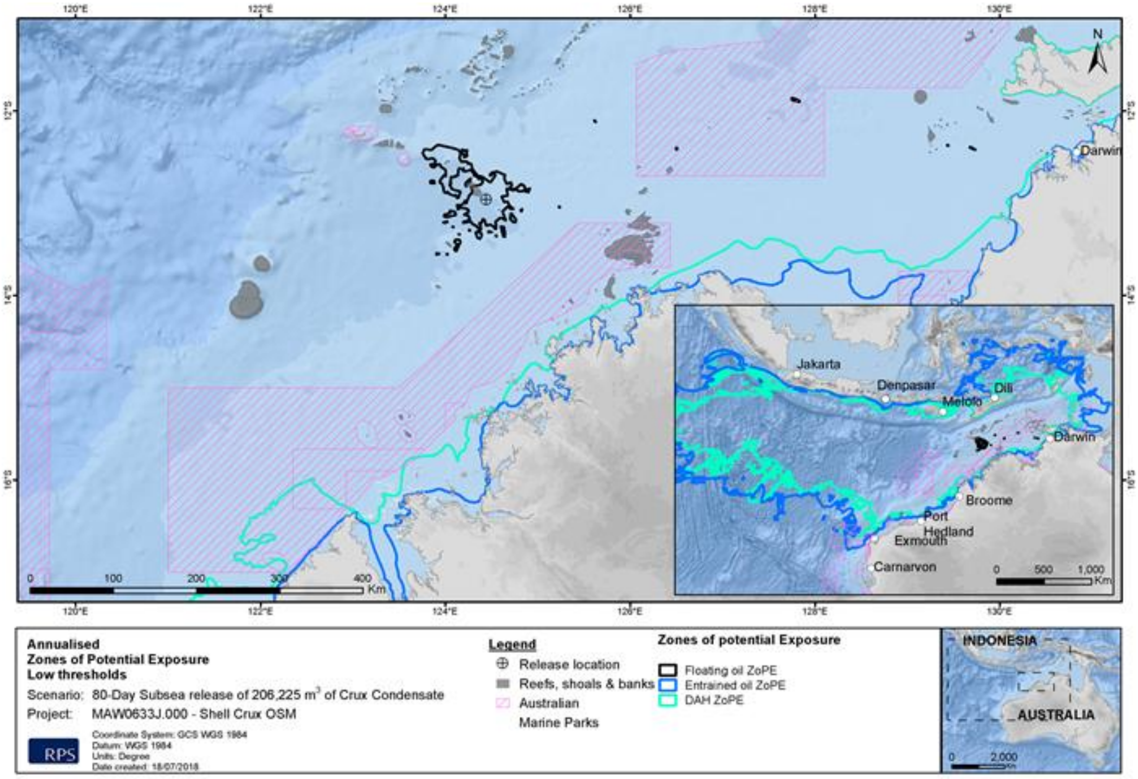



Figure 8-28: Predicted Annualised Low Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an 80-day Subsurface Release of Crux Condensate at a Development Well

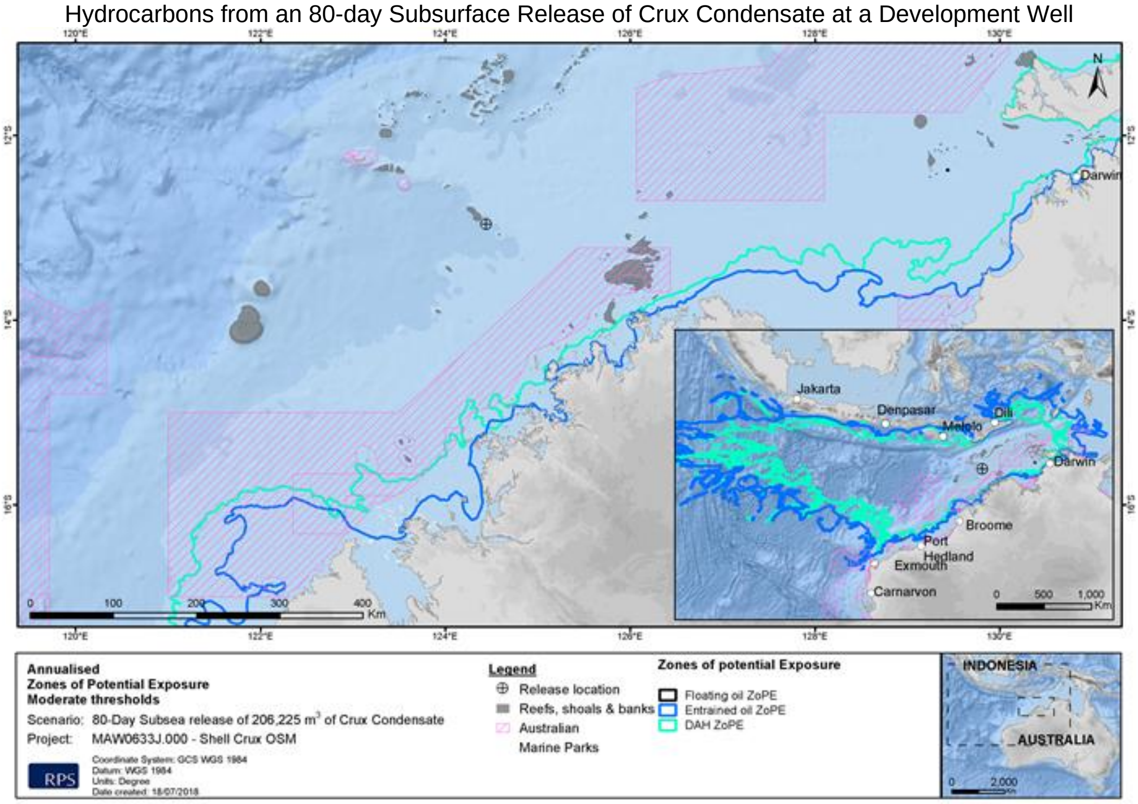



Figure 8-29: Predicted Annualised Moderate Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an 80-day Subsurface Release of Crux Condensate at a Development Well

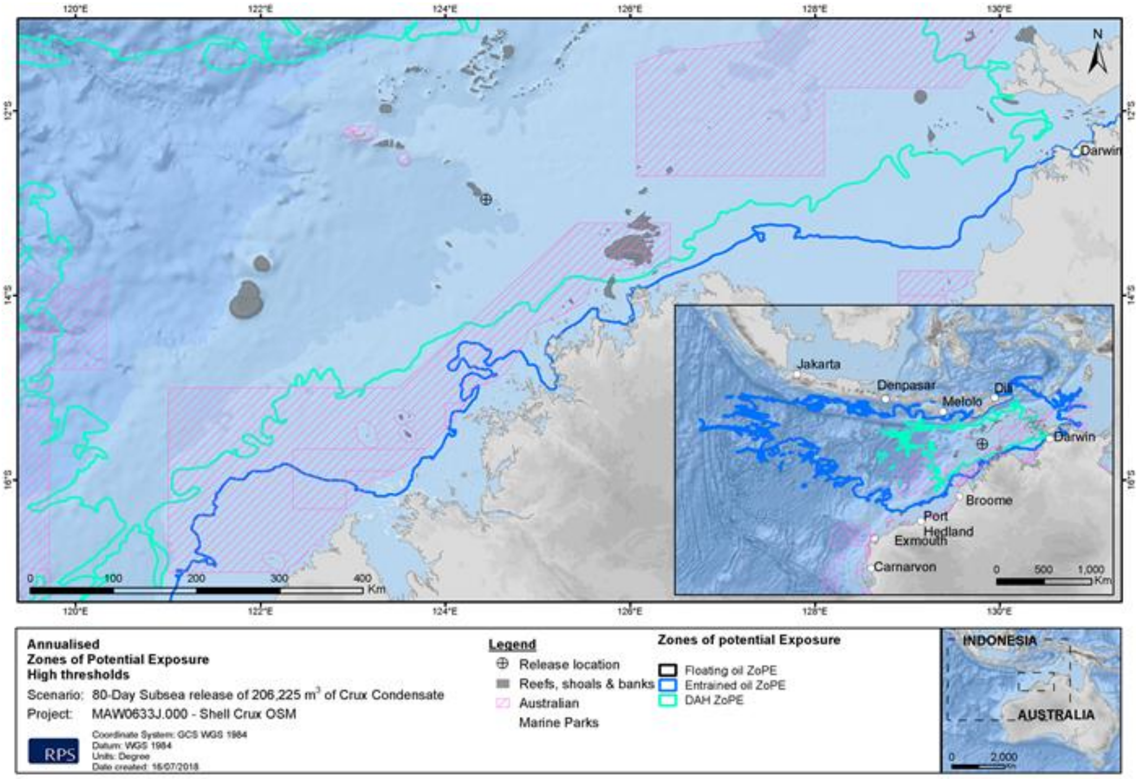



Figure 8-30: Predicted Annualised High Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an 80-day Subsurface Release of Crux Condensate at a Development Well

*Loss of Process Storage Tank Containment*

The worst-case deterministic run, determined to be the deterministic model run from the stochastic set with the greatest volume of hydrocarbons accumulating on shorelines, is shown in **Figure 8-31**. This deterministic run resulted in approximately 2 $m^3$ of hydrocarbon accumulation on the shorelines within the Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF.

This worst-case deterministic run indicated that hydrocarbons on the sea surface mainly drifted north-west of the release location. The potential floating oil exposure zones were shown up to 57 km, 8 km and 1 km of the release location at the low, moderate and high thresholds, respectively. The entrained oil and dissolved aromatic hydrocarbons were shown to move west of the release location. Low entrained hydrocarbons were recorded up to 304 km from the release location. Low dissolved aromatic hydrocarbons were observed up to 1 km from the release location.

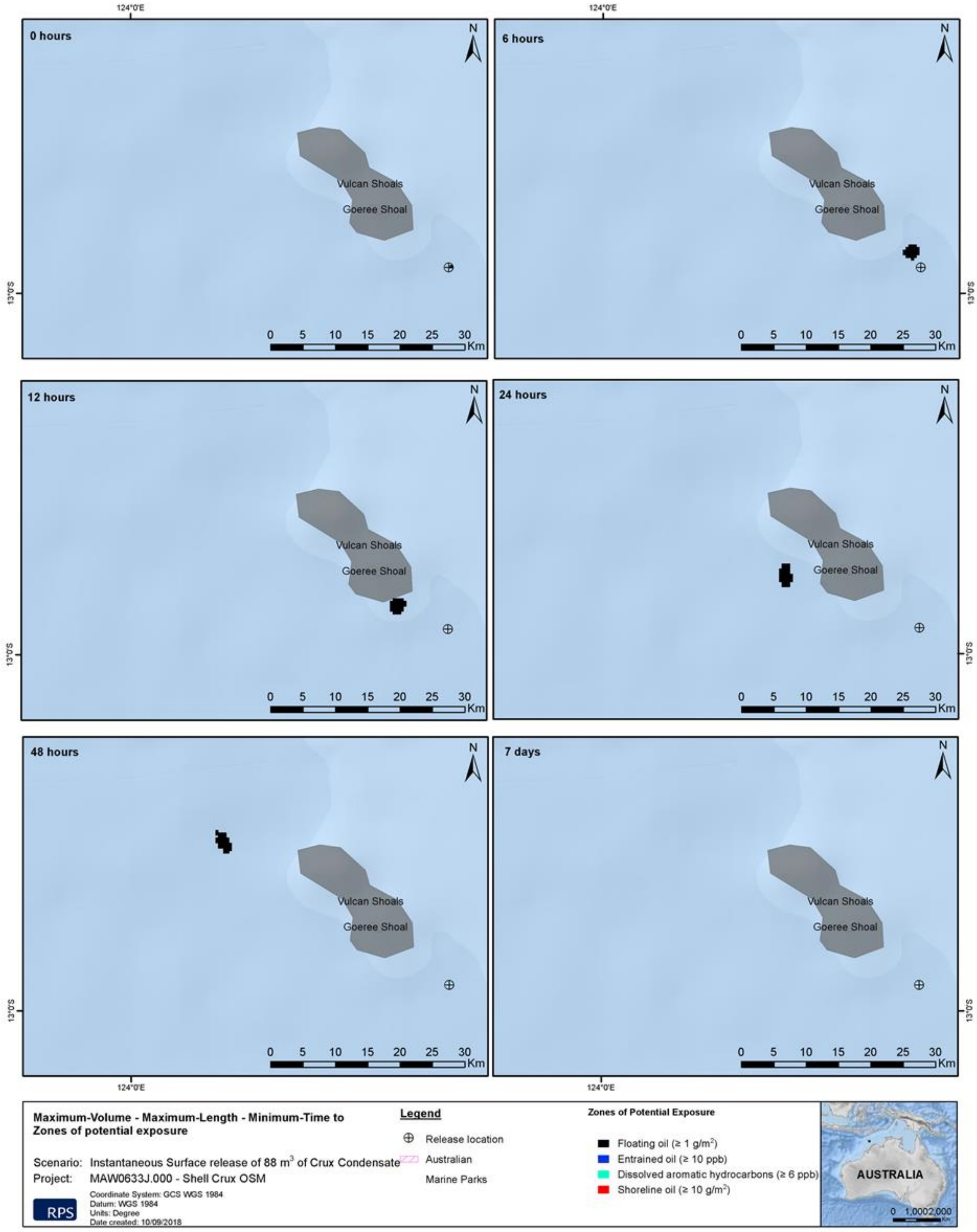



Figure 8-31: Time-varying Areal Extent of Potential Exposure at Floating, Entrained, Dissolved Hydrocarbon and Shoreline Hydrocarbon Low Exposure Threshold Concentrations Resulting from an Instantaneous Release of Crux Condensate at the Crux Platform

Key results from the stochastic modelling studies for a worst-case loss of process storage tank containment showed:

- the surface release results in a high probability of formation of a floating hydrocarbon slick (**Figure 8-32** and **Figure 8-33**), which is expected to evaporate and weather rapidly due to the high portion of volatile hydrocarbons. The maximum distance to the outer extent of the low floating oil threshold is predicted to vary between seasons, extending to within 116 km, 115 km and 81 km during winter, summer and transitional conditions, respectively. The area affected by floating oil above the moderate and high floating oil thresholds was further reduced, with floating oil not predicted to extend beyond 17 km in any season.
- potential for accumulation of hydrocarbons on shorelines is predicted to be low, with a maximum accumulated volume of 2 $m^3$ forecast at Ashmore Reef and Cartier Island, and maximum local accumulated concentration on shorelines of 127 $g/m^2$ forecast at Ashmore Reef and Cartier Island.
- entrained oil concentrations were predicted to disperse in all direction from the release location (**Figure 8-32**, **Figure 8-33**, **Figure 8-34**), depending on metocean conditions. The maximum distance to the outer extent of the low entrained oil threshold is predicted to vary between seasons, extending up to 566 km, 541 km and 402 km during summer, winter and transitional conditions, respectively. The maximum extent is forecast to be reduced for the moderate and high thresholds for all the seasons.
- dissolved hydrocarbons (**Figure 8-32**, **Figure 8-33**, **Figure 8-34**) were predicted to follow a similar distribution to entrained hydrocarbons and extend in all directions from the release location. The maximum distance to the outer extent of the low dissolved aromatic hydrocarbon threshold is predicted to vary between seasons, extending up to 465 km, 427 km and 216 km during summer, winter and transitional conditions, respectively. The maximum extent is forecast to be reduced for the moderate (50 ppb) and high (≥ 400 ppb) thresholds for all the seasons.
- the surface release of Crux condensate from a loss of process tank containment will spread rapidly, with volatile components (approximately 55%) evaporating within the first 12 hours (RPS 2018d). The remaining components will continue to evaporate of the course of several days, leaving approximately 8% residual hydrocarbons by mass. Local wind and wave conditions may entrain floating hydrocarbons, although the resulting entrained droplets may resurface and reform floating slicks.
- as with the worst-case loss of well containment scenario, metocean conditions were a significant influence on the distribution of entrained and dissolved hydrocarbons. Unlike the worst-case loss of well containment scenario, the entrained and dissolved hydrocarbons were concentrated in surface waters due to the relatively large droplet size and different entrainment mechanisms (i.e. wave action on floating oil versus a turbulent subsea plume).

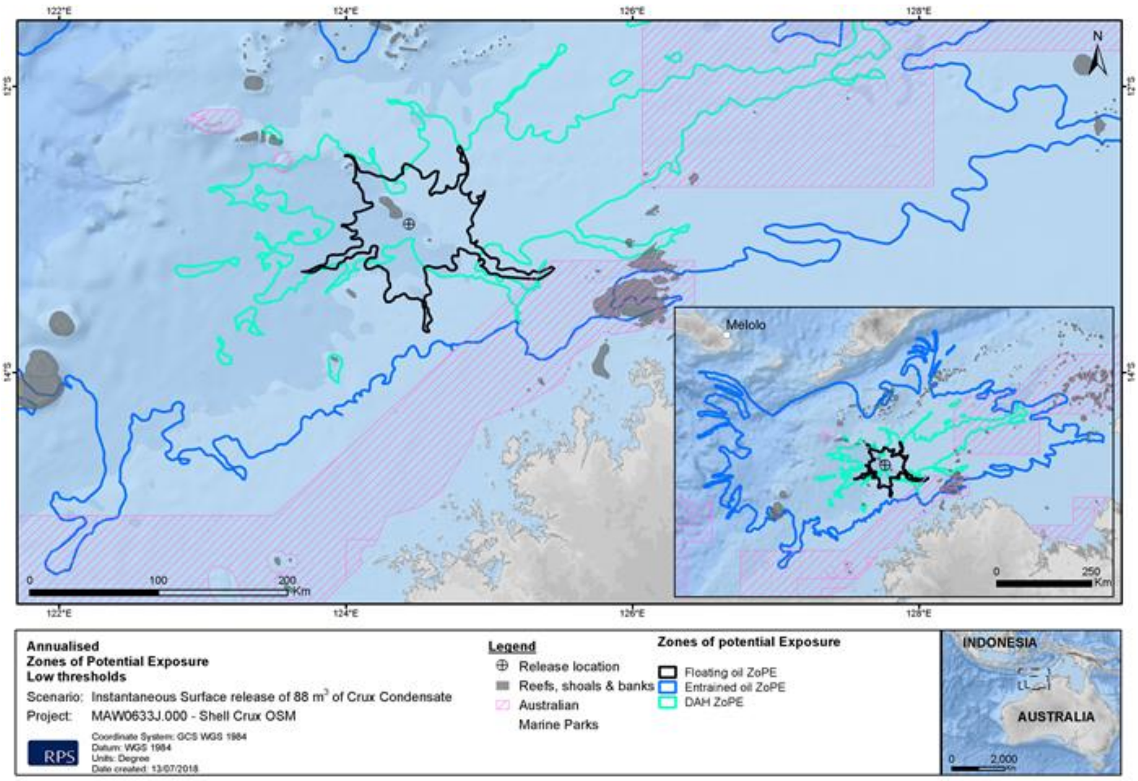



Figure 8-32: Predicted Annualised Low Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an Instantaneous Surface Release of Crux Condensate at the Crux Platform

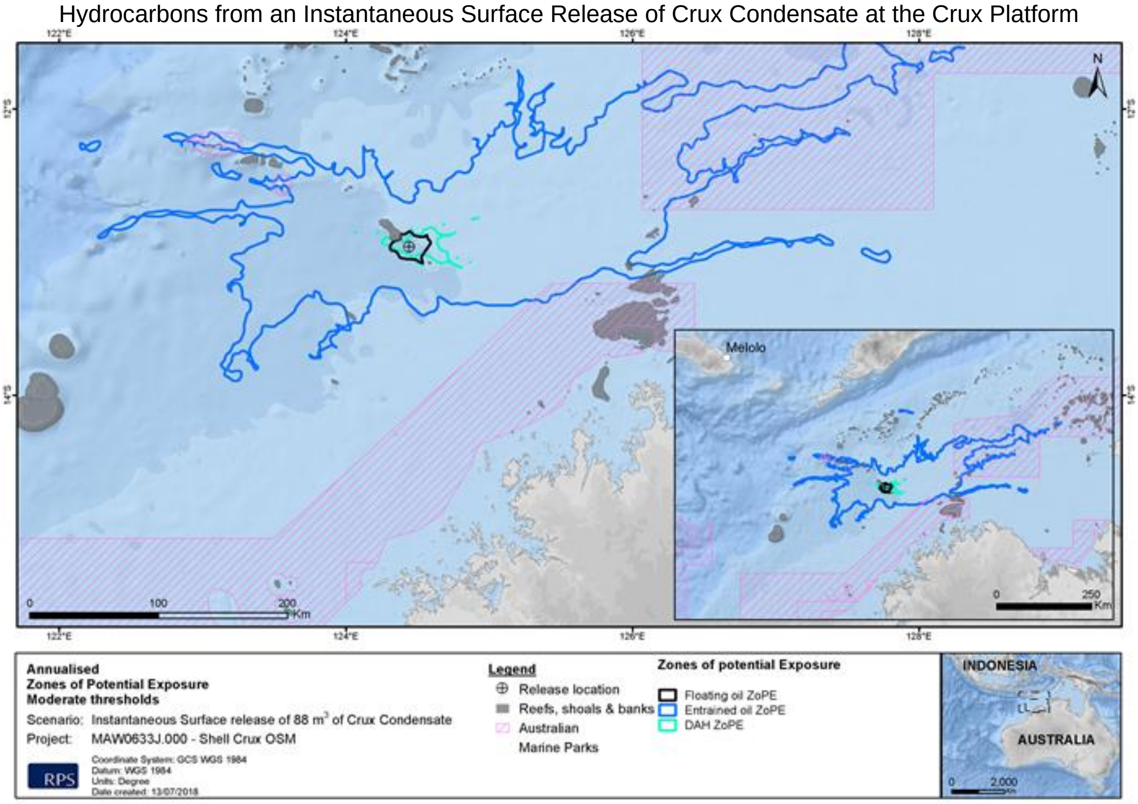



Figure 8-33: Predicted Annualised Moderate Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an Instantaneous Surface Release of Crux Condensate at the Crux Platform

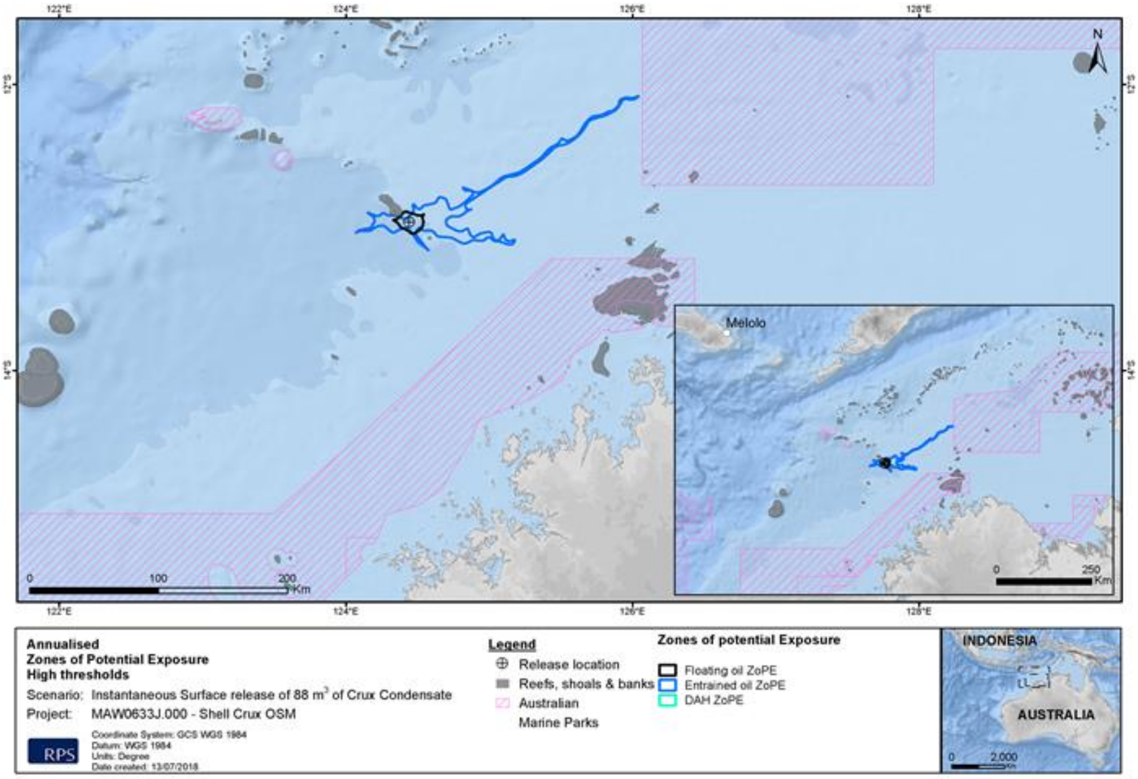



Figure 8-34: Predicted Annualised High Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from an Instantaneous Surface Release of Crux Condensate at the Crux Platform

*Loss of Containment from Crux Export Pipeline*

The worst-case deterministic run, determined to be the deterministic model run form the stochastic set with the greatest volume of hydrocarbons accumulating on shorelines, is shown in **Figure 8-35**. This deterministic run resulted in approximately 116 $m^3$ of hydrocarbon accumulation on the shorelines within at Ashmore Reef and Cartier Island and Surrounding Commonwealth Waters KEF.

This worst-case deterministic run indicated that hydrocarbons on the sea surface mainly drifted north-west of the release location. The potential floating oil exposure zones were shown up to 312 km, 34 km and 14 km of the release location at the low, moderate and high thresholds, respectively. The entrained oil and dissolved aromatic hydrocarbons were shown to move west and south-west of the release location. Low, moderate and high entrained hydrocarbons were recorded up to 1,419 km, 1,323 km and 12 km, respectively, from the release location. Low and moderate dissolved aromatic hydrocarbons were observed up to 428 km, 276 km, respectively, from the release location.

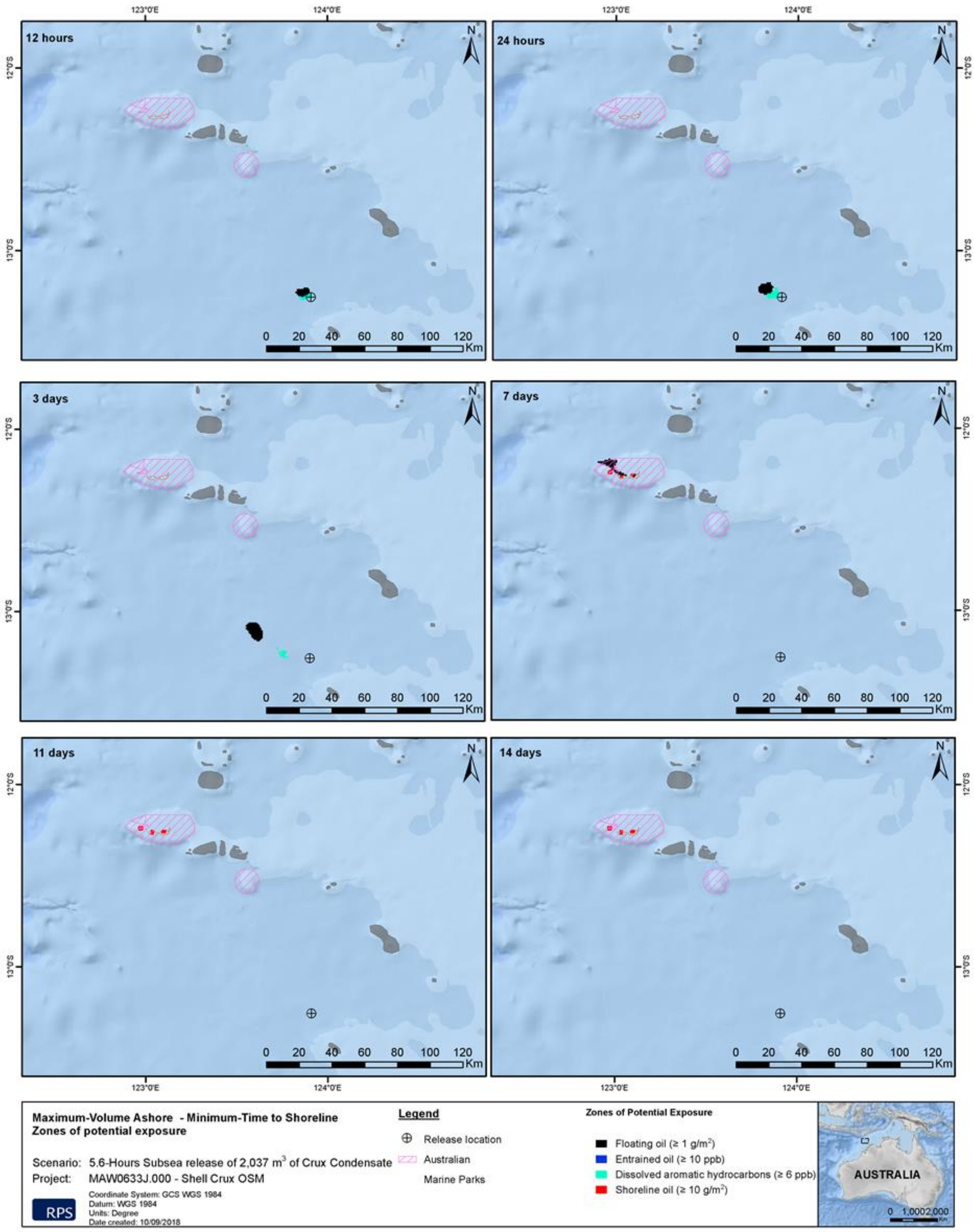



Figure 8-35: Time-varying Areal Extent of Potential Exposure at Floating, Entrained, Dissolved Hydrocarbon and Shoreline Hydrocarbon Low Exposure Threshold Concentrations Resulting from a 5.6-hour Subsurface Release of Crux Condensate from the Export Pipeline

Key results from the stochastic modelling studies for a worst-case loss of containment from the export pipeline showed:

- the maximum distance to the outer extent of the low floating oil threshold is predicted to vary between seasons, extending to within 581 km during summer and within 330 km during winter and transitional conditions. The maximum extent is forecast to be reduced for the moderate and high thresholds for all the seasons (**Figure 8-36**, **Figure 8-37** and **Figure 8-38**).
- potential for accumulation of hydrocarbons on shorelines is predicted to be low, although the worst-case maximum accumulated volume of 116 $m^3$ forecast at Ashmore Reef AMP would result in considerable hydrocarbon contamination. Maximum local accumulated concentration on shorelines of 3,131 $g/m^2$ forecast at Ashmore Reef AMP during a release starting in the transitional period.
- entrained oil concentrations were predicted to disperse in all direction from the release location (**Figure 8-36**, **Figure 8-37** and **Figure 8-38**), depending on metocean conditions. The maximum distance to the outer extent of the low entrained oil threshold is predicted to vary between seasons, extending up to 1,770 km, 1,419 km and 780 km during winter transitional and summer conditions, respectively. The maximum extent is forecast to be reduced for the moderate and high thresholds for all the seasons.
- dissolved hydrocarbons (**Figure 8-36**, **Figure 8-37** and **Figure 8-38**) were predicted to follow a similar distribution to entrained hydrocarbons and extend in all directions from the release location. The maximum distance to the outer extent of the low dissolved aromatic hydrocarbon threshold is predicted to vary between seasons, extending up to 1,770 km, 754 km and 671 km during winter, summer and transitional conditions, respectively. The maximum extent is forecast to be slightly reduced for the moderate and high thresholds for all the seasons.
- the loss of containment from the export pipeline will generate a buoyant plume of gas and condensate, although at considerably lower pressure than the worst-case loss of well containment. The subsequent turbulent mixing in the water column will result in larger entrained oil droplets (approximately 500 µm to 2.5 mm), which will rise towards the sea surface (approximately 1.6-10 cm per second). These droplets are more likely to result in floating slicks than those formed by a well blowout, although the floating slick may become entrained due to surface wind and wave conditions (RPS 2018d).
- as with the worst-case loss of well containment scenario, metocean conditions were a significant influence on the distribution of entrained and dissolved hydrocarbons. Unlike the worst-case loss of well containment scenario, the entrained and dissolved hydrocarbons were concentrated in surface waters due to the relatively large droplet size and different entrainment mechanisms (i.e. wave action on floating oil versus a turbulent subsea plume).

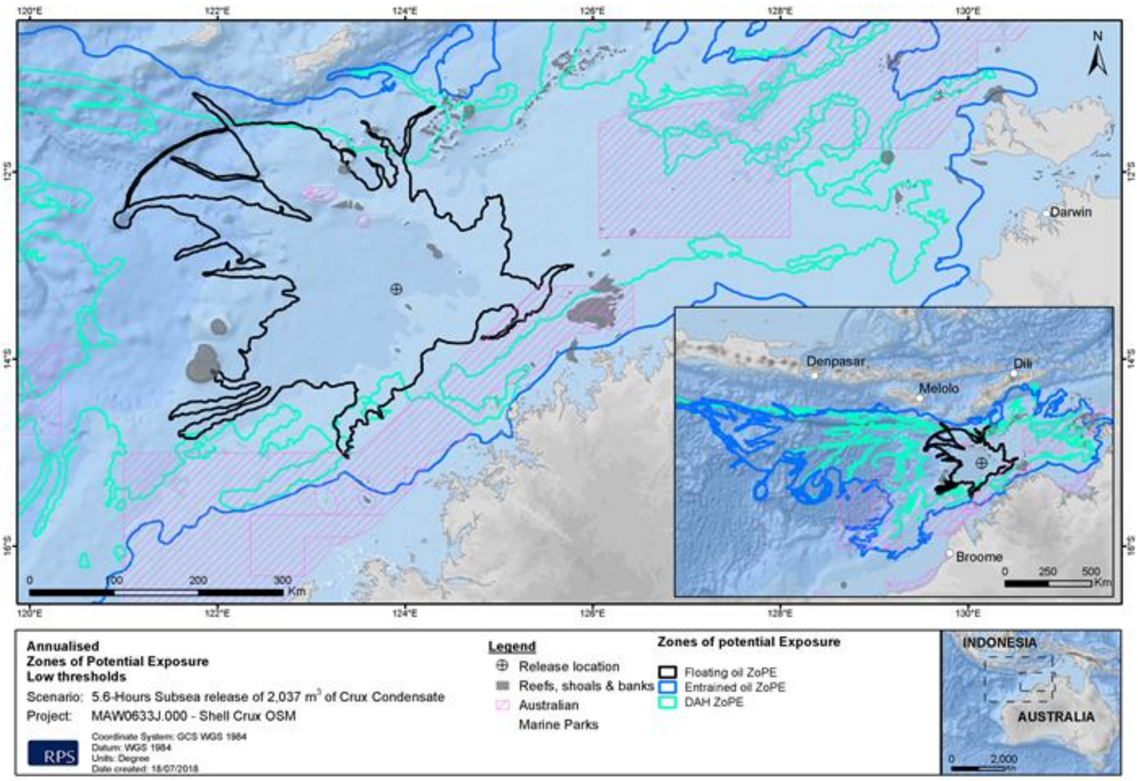



Figure 8-36: Predicted Annualised Low Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 5.6-hour Subsurface Release of Crux Condensate from the Export Pipeline

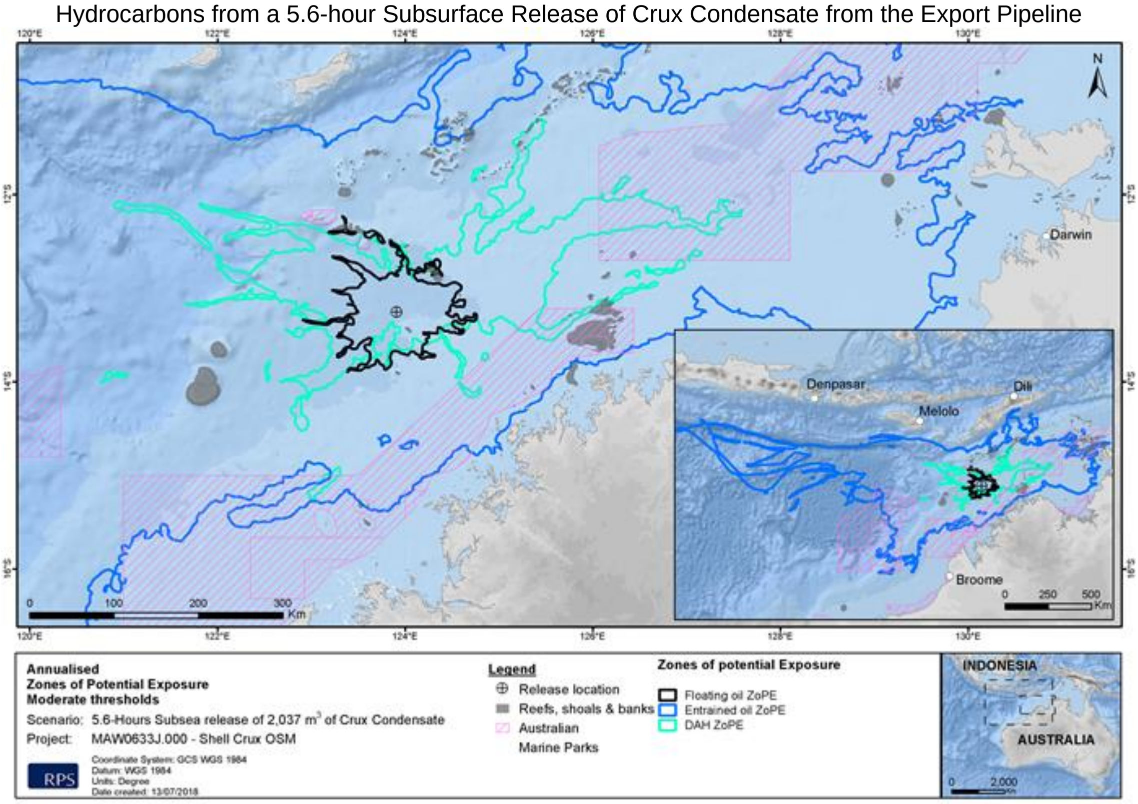



Figure 8-37: Predicted Annualised Moderate Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 5.6-hour Subsurface Release of Crux Condensate from the Export Pipeline

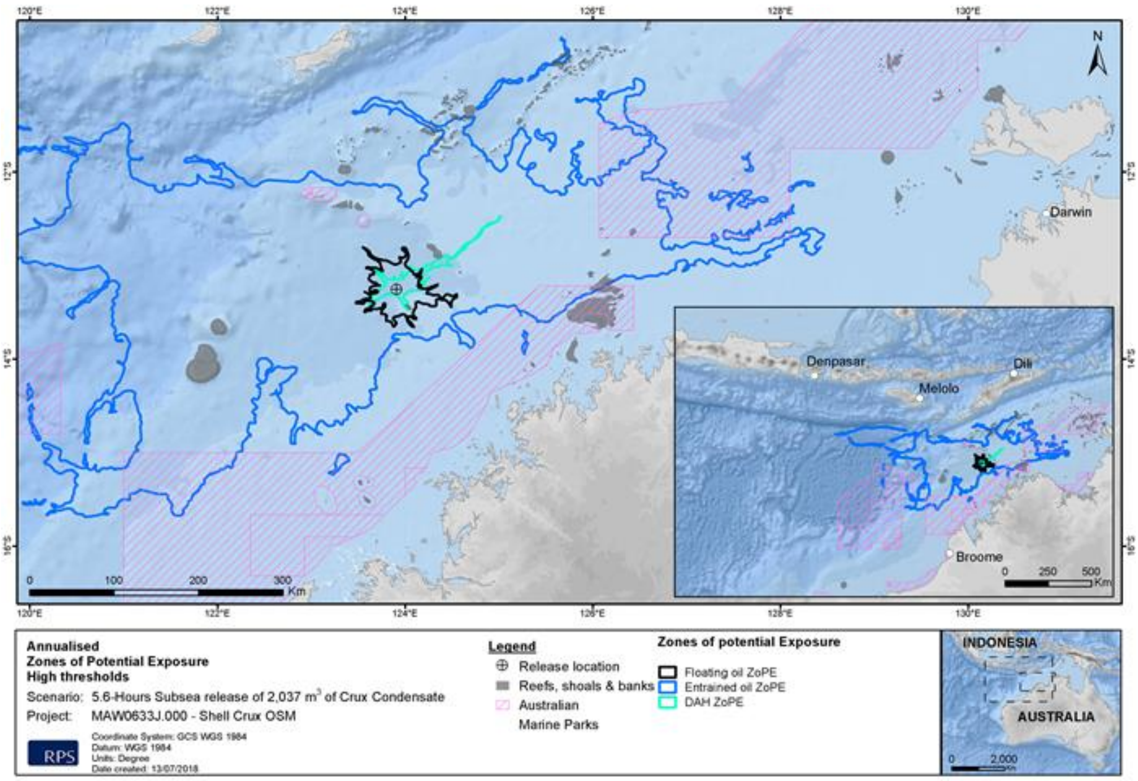



Figure 8-38: Predicted Annualised High Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 5.6-hour Subsurface Release of Crux Condensate from the Export Pipeline

*Loss of Fuel from Vessel*

The worst-case deterministic run, determined to be the deterministic model run form the stochastic set with the greatest volume of hydrocarbons accumulating on shorelines, is shown in **Figure 8-39**. This deterministic run resulted in approximately 624 $m^3$ of hydrocarbon accumulation on the shorelines associated with the Bonaparte Archipelago/Bigge Island.

Hydrocarbons on the sea surface mainly drifted south of the release location. The potential floating oil exposure zones were shown up to 198 km, 190 km and 159 km of the release location at the low, moderate and high thresholds, respectively. There was no entrained oil or dissolved aromatic hydrocarbon exposure predicted at any threshold.

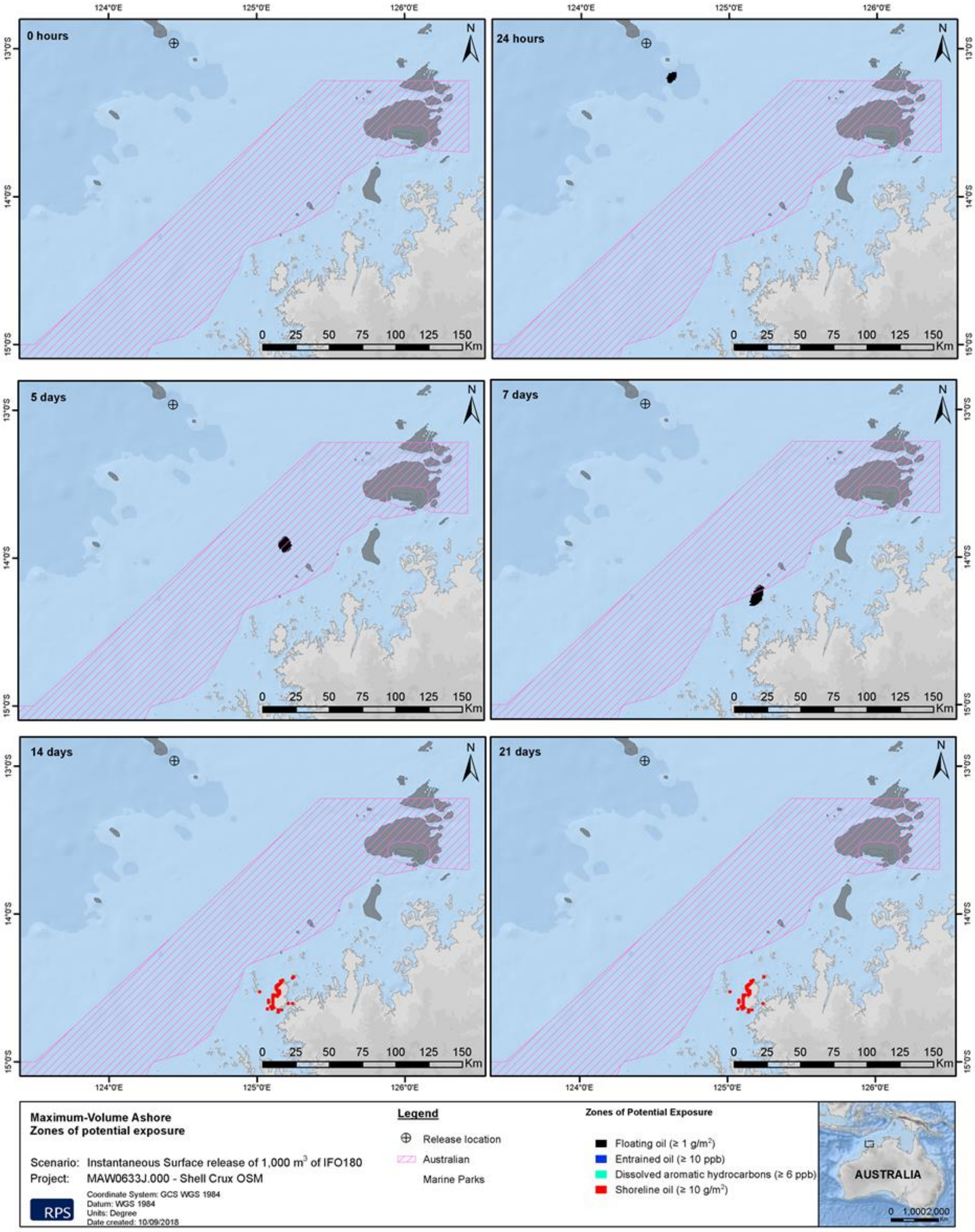



Figure 8-39: Time-varying Areal Extent of Potential Exposure at Floating, Entrained, Dissolved Hydrocarbon and Shoreline Hydrocarbon Low Exposure Threshold Concentrations Resulting from a 1-hour Surface Release of IFO at the Crux End of the Export Pipeline

Key results from the stochastic modelling studies for a worst-case loss of fuel from a vessel showed:

- floating IFO may disperse in all directions, depending on metocean conditions (**Figure 8-40**, **Figure 8-41** and **Figure 8-42**). The maximum distance to the outer extent of the low floating oil low threshold is predicted to vary between seasons, extending to within 1,853 km, 1,249 km and 985 km during winter, summer, and transitional conditions, respectively. The area potentially contacted above the moderate and high floating oil threshold was reduced, with floating oil not predicted to extend beyond 1,061 km, 727 km and 484 km, during winter, summer, and transitional conditions, respectively.
- potential for accumulation of oil on shorelines is predicted to be low, although the worst-case maximum accumulated volume of 771 $m^3$ forecast at Bonaparte Archipelago and Kimberley PMZ would result in considerable hydrocarbon contamination. Maximum local accumulated concentration on shorelines of 7,777 $g/m^2$ forecast at Bonaparte Archipelago, Kimberley PMZ and Kimberley Coast during a release starting in the summer period.
- entrained oil concentrations are expected to be localised to the release location. The high viscosity of IFO means the potential for entrainment during typical metocean conditions is relatively low. The maximum distance to the outer extent of the low entrained oil threshold is predicted to vary between seasons, extending up to 170 km, 102 km and 24 km during summer, transitional and winter conditions, respectively. The maximum extent is forecast to be greatly reduced for the moderate and high thresholds for all the seasons.
- dissolved hydrocarbons will be localised to the release location. The maximum distance to the outer extent of the low dissolved aromatic hydrocarbon threshold is predicted only in the summer season, extending up to 20 km.

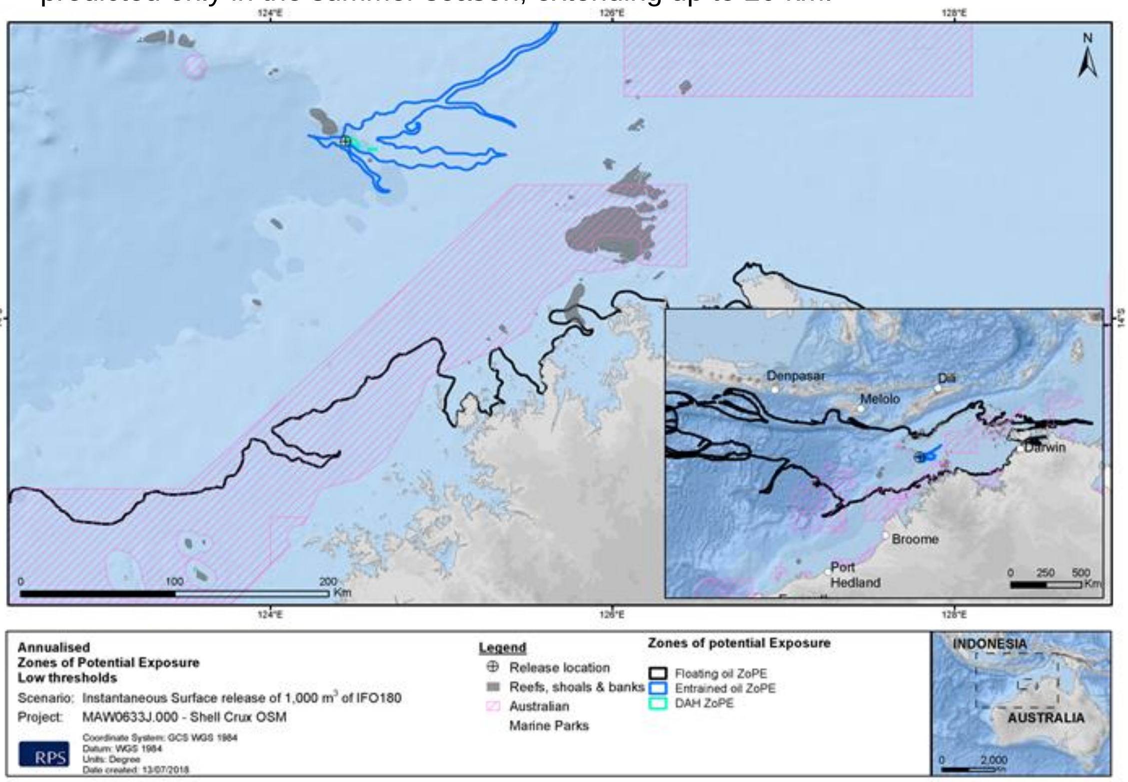



Figure 8-40: Predicted Annualised Low Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 1-hour Surface Release of IFO-180 at the Crux End of the Export Pipeline

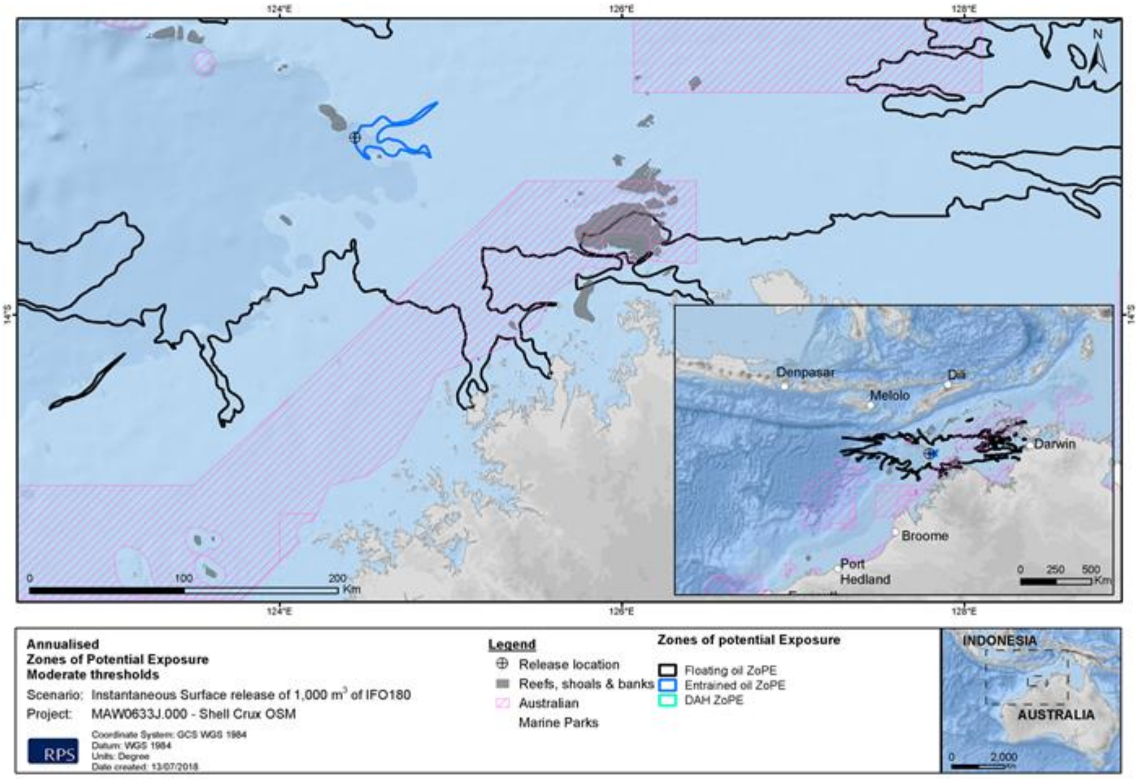



Figure 8-41: Predicted Annualised Moderate Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 1-hour Surface Release of IFO-180 at the Crux End of the Export Pipeline

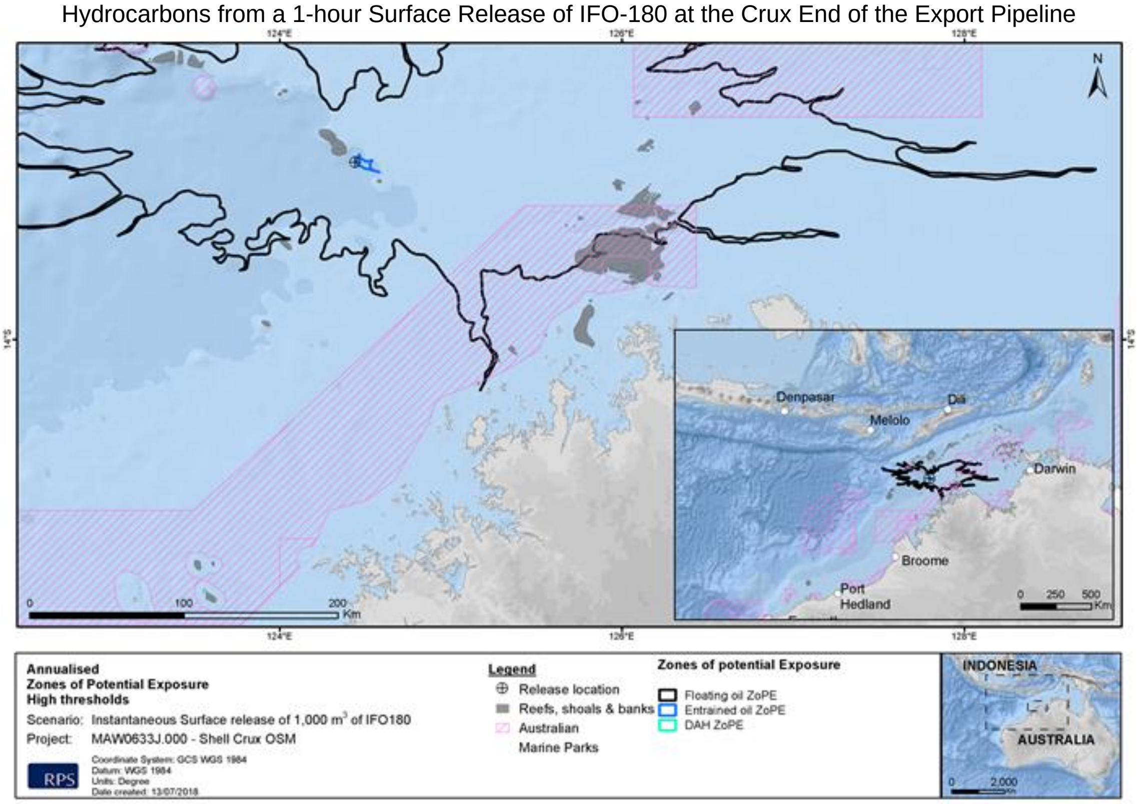



Figure 8-42: Predicted Annualised High Exposure Threshold for Floating, Entrained and Dissolved Hydrocarbons from a 1-hour Surface Release of IFO-180 at the Crux End of the Export Pipeline

### 8.4.9.3 Description and Evaluation of Impacts and Risks

Table 8-48: Summary of Hydrocarbon Spill Modelling Results for Receptors with ≥ 50 % Likelihood of Contact above Moderate or High Thresholds

| Receptor Category | Hydrocarbon Phase Above Adverse Exposure Threshold | | | |
|---|---|---|---|---|
| | Floating | Accumulated | Entrained | Dissolved |
| *Shoals and Banks* | | | | |
| Barracouta Shoals | | | 1 | 1 |
| Deep Shoal 1 | | | 1 | |
| Echuca Shoal | | | 1 | |
| Eugene McDermott Shoal | | | 1 | 1 |
| Gale Bank | | | 1 | |
| Goeree Shoal | | | 1 | 1 |
| Heywood Shoal | | | 1 | 1 |
| Johnson Bank | | | 1 | |
| Vulcan Shoals | | | 1 | 1 |
| Woodbine Bank | | | 1 | 1 |
| *Reefs and Offshore Islands* | | | | |
| Browse Island | | | 1 | |
| Seringapatam Reef | | | 1 | |
| Scott Reef North | | | 1 | |
| Scott Reef South | | | 1 | |
| Sandy Islet | | | 1 | |
| *Mainland Coastlines* | | | | |
| No coastlines with likelihood of contact > 50% | | | | |
| *KEFs* | | | | |
| Ancient coastline at 125 m depth contour | | | 1 | 1 |
| Ashmore Reef and Cartier Island and surrounding Commonwealth waters | | | 1 | 1 |
| Carbonate bank and terrace system of Sahul Shelf | | | 1 | 1 |
| Continental slope demersal fish communities | | | 1 | 1 |
| Seringapatam Reef and Commonwealth waters in the Scott Reef Complex | | | 1 | |
| *BIAs* | | | | |
| Flatback turtle | | | 1 | 1 |
| Green turtle | | | 1 | 1 |
| Hawksbill turtle | | | 1 | |
| Loggerhead turtle | | | 1 | 1 |
| Olive ridley turtle | | | 1 | 1 |
| *Habitat Critical to the Survival of a Species* | | | | |
| Green turtle | | | 1 | 1 |
| *Heritage* | | | | |
| Ashmore Reef National Nature Reserve | | | 1 | 1 |
| Scott Reef and Surrounds – Commonwealth Area | | | 1 | |

| Receptor Category | Hydrocarbon Phase Above Adverse Exposure Threshold | | | |
|---|---|---|---|---|
| | Floating | Accumulated | Entrained | Dissolved |
| *Ramsar Wetlands* | | | | |
| Ashmore Reef National Nature Reserve | | | 1 | 1 |
| *Marine Parks* | | | | |
| Ashmore Reef AMP | | | 1 | |
| Cartier Island AMP | | | 1 | 1 |
| Kimberley AMP | | | 1 | |
| Oceanic Shoals AMP | | | 1 | 1 |
| *Fisheries* | | | | |
| Northern Prawn Fishery | | | 1 | |
| NWSTF | | | 1,3 | 1 |
| Southern Bluefin Tuna Fishery | 2, 3, 4 | | 1, 3 | 1 |
| Western Skipjack Fishery | 2, 3, 4 | | 1, 3 | 1 |
| Western Tuna and Billfish Fishery | 2, 3, 4 | | 1, 3 | 1 |
| *Defence* | | | | |
| No defence areas with likelihood of contact > 50% | | | | |
| *Offshore Petroleum* | | | | |
| Montara Production Platform | | | 1 | 1 |
| Prelude FLNG | | | 1 | 1 |
| *Indonesia and Timor-Leste Coastlines* | | | | |
| No Indonesian or Timorese coastlines with likelihood of contact > 50% | | | | |

Scenarios – loss of well control (1), loss of process storage tank containment (2), loss of containment from the export pipeline (3) and loss of fuel from vessel (4)

**Physical Environment**

*Water Quality*

Large volume releases of Crux condensate have the potential to result in increased concentrations of dissolved hydrocarbons, which include BTEX and PAHs. There low molecular weight compounds are known to be toxic to marine biota (refer to **Ecosystems, Communities and Habitats** and **Threatened Species and Ecological Communities** below for a discussion of these effects). BTEX compounds do not persist in the environment due to their volatility and will diminish once released into the environment. The concentration of BTEX is expected to be highest near the release location and will decline as the spilled hydrocarbon weathers. PAHs are less volatile than BTEX and are expected to persist for longer in the environment.

The decrease in water quality from worst-case hydrocarbon spill are expected to consist of short-term acute toxic effects to phytoplankton and zooplankton. Planktonic communities are characterised by relatively rapid turnover rates of short-lived biota. The high turnover rate will lead to rapid recovery as the spilled hydrocarbons decay in the environment. Within plankton communities, there is evidence from laboratory studies that some taxonomic groups, particularly zooplankton (e.g. copepods) may be more sensitive to hydrocarbon pollution (Almeda et al. 2013; Jiang et al. 2010). Few reliable studies have shown any impacts of hydrocarbon spills on planktonic communities, with most studies concluding that impacts from hydrocarbon pollution cannot be distinguished from natural variability (Abbriano et al. 2011; Davenport et al. 1982; Varela et al. 2006).

The concentrations of hydrocarbons in the water column will decrease over time once the release has stopped due to processes such as dispersion, dilution, physical and biological degradation, and evaporation. For short duration release scenarios, these processes will begin to reduce the total amount of hydrocarbons in the water column shortly after the release. The worst-case loss of well containment will continue to release fresh hydrocarbons for the duration of the release, and the amount of hydrocarbons will increase until the release is stopped.

*Sediment Quality*

Sediment quality is not expected to be significantly affected by any of the worst-case scenarios that release Crux condensate. Hydrocarbon contaminants (e.g. PAHs) from surface releases are unlikely to reach the seabed due to the water depth and low natural sedimentation rates in the region. Hydrocarbon contaminants from the subsea releases (loss of well control and loss of pipeline containment) may contaminate sediments by advective transport of the plume that will be formed during the release (Romero et al. 2015). This is considered most likely to occur with the worst-case loss of well containment scenario due to the relatively long duration of the release. Any resulting contamination will be concentrated around, and down-current from, the wellhead. Due to the low density and volatile nature of the hydrocarbon, weathered condensate is unlikely to be deposited to the seabed.

The IFO release from a loss of fuel from a vessel scenario has a relatively low portion of volatiles, which are expected to evaporate quickly following release. The remaining IFO may sink to the seabed if exposed to considerable sedimentary particles, however this is considered very unlikely to occur in the open sea due to the low density of the residual IFO relative to seawater and the naturally low sedimentation rates. Residual IFO near shorelines may be exposed to higher sediment loads and be more likely to sink. Stranding of residual IFO on shorelines can lead to long-term contamination of sediments with high-molecular weight hydrocarbons. These compounds are typically much less toxic than low-molecular weight hydrocarbons.

*Air Quality*

The gas plume from the worst-case loss of well containment and loss of pipeline containments scenarios will result in a gas cloud upon reaching the surface. This potentially large gas cloud is expected to disperse rapidly in the open, offshore environment.

The formation of a gas cloud poses a significant health and safety risk from the formation of explosive mixtures and asphyxiation. Given the highly localised extent and expected short duration of the gas cloud, this risk is considered to be very low.

**Ecosystems, Communities and Habitats**

*Benthic Communities*

Seabed releases of Crux condensate may result in impacts to water quality and sediments in the vicinity of the release location (refer to sections **Water Quality** and **Sediment Quality** above). The seabed in the vicinity of these potential release locations (i.e. the project area) are characterised by unconsolidated sediments which host spare assemblages of filter feeding and deposit feeding organisms. These fauna may be subject to acute and chronic toxic effects from exposure to hydrocarbons, however the extent of the affected habitat is expected to be localised to the vicinity of the release location. Bare sediment habitat is very widely represented in the Timor Sea, and the associated fauna assemblages are not considered to be particularly sensitive of or high conservation value.

Many benthic fauna species have planktonic larval phases (e.g. corals, echinoderms, sponges etc.). Organisms with planktonic larval phases typically produce very high numbers of larvae. A worst-case credible spill may result in increased mortality of planktonic larvae (which are subject to high natural mortality); however, this is not expected to result in population-scale impacts.

Filter feeding benthic communities may be vulnerable to entrained and dissolved hydrocarbons. Entrained hydrocarbons can be ingested by filter feeders, leading to increased exposure due to accumulation of ingested oil droplets (Payne and Driskell 2003). While typically less toxic than dissolved hydrocarbons, entrained oil may still cause toxic effects; entrained oil may also result in physical impacts such as clogging of filter feeding organs, potentially resulting in reduced feeding efficiency. Filter feeder, and sessile organisms in general, may be exposed to concentrations of dissolved hydrocarbons that result in acute and chronic toxic effects.

Results from modelling studies of the worst-case loss of well containment and pipeline release scenarios indicated that several offshore reefs and islands, and bank and shoals, may be contacted by hydrocarbons above impact thresholds. Refer to **Offshore Reefs and Islands** and **Shoals and Banks** below for a discussion of potential impacts to these receptors.

Nearshore benthic communities are typically more diverse than those found in the deep-water habitat of the project area, often due to the presence of primary producers, such as seagrasses, macroalgae, zooxanthellate corals and mangroves.

Most seagrasses within the area that may be affected by the worst-case hydrocarbon spill scenarios are subtidal, although there may be relatively small areas of intertidal seagrasses along the WA and NT coastlines. Seagrass in the subtidal and intertidal zones have different degrees of exposure to hydrocarbon spills. Subtidal seagrass is unlikely to be exposed to spilled hydrocarbons, as most hydrocarbons in subtidal environments will be concentrated at the surface. Intertidal seagrasses are vulnerable to smothering by floating oil slicks, which can lead to mortality if it coats their flowers, leaves and stems (Dean et al. 1998; Taylor and Rasheed 2011). Long-term impacts to seagrass are unlikely unless hydrocarbon is retained within the seagrass meadow for a sustained duration (Wilson and Ralph 2011). Toxicity effects can also occur due to absorption of soluble fractions of hydrocarbons into tissues (Runcie et al. 2010). The potential for toxicity effects of entrained hydrocarbons may be reduced by weathering processes that should serve to lower the content of soluble aromatic components before contact occurs.

Like seagrasses, the potential impacts to macroalgae depend on the exposure pathway; most macroalgae in the region are subtidal, although intertidal macroalgae may be present. Studies of subtidal macroalgal assemblages exposed to fuel oil spills have shown that impacts from exposure is slight (Edgar et al. 2002; Lobón et al. 2008). Effects of exposure to oil on intertidal macroalgae are more variable; some studies reported little evidence of impacts (Díez et al. 2009), while others show significant impacts (De Vogelaere and Foster 1994). Recovery of intertidal macroalgae has been shown to occur faster in areas where oil has been left to degrade naturally compared to areas subject to intensive clean-up operations (De Vogelaere and Foster 1994). Given the potential for shoreline contact is very low in all the worst-case spill scenarios, impacts to macroalgae are considered to be highly unlikely.

Subtidal and intertidal zooxanthellate corals occur widely throughout the Timor Sea, including around offshore reefs and islands, bank and shoals, and the mainland coast. Shallow subtidal and intertidal corals may be coated by stranded floating hydrocarbons during low tides, which may subsequently be re-floated by subsequent incoming tides. Impacts from physical coating of corals appears to also depend on coral morphology. Coral species more likely to retain oil coatings (e.g. due to polyp morphology, or gross morphology with high surface area to volume ratios such as branching corals) have been shown to be more susceptible to impacts (Shigenaka 2001). Exposure to dissolved and entrained hydrocarbons may result in acute and chronic toxic effects, with longer exposure durations typically leading to greater potential for mortality (Shigenaka 2001). Corals may also ingest entrained oil particles, potentially leading to update of hydrocarbons into coral tissue (Loya and Rinkevich 1980).

Intertidal mangrove habitats occur throughout much of Kimberley and NT coastline, and are highly susceptible to oil pollution (NOAA 2014). Given the distance between potential release locations and the nearest mangroves, any spilled hydrocarbons reaching mangroves will be highly weathered. Mangroves are vulnerable to contact with floating hydrocarbons, such as weathered IFO, which may coat prop roots and pneumatophores (aerial roots that support oxygen uptake) (Duke and Archibald 2016). Exposure can result in direct effects such as yellowed leaves, defoliation and mortality, and indirect effects such as reduced recruitment and increased sensitivity to other stressors (NOAA 2014). Like seagrasses, mangroves can also be impacted by entrained and dissolved aromatic hydrocarbons either in the water or sediment

*Shoals and Banks*

The Timor Sea region hosts numerus named shoals and banks, a number of which were identified by the stochastic modelling as being contacted by entrained and dissolved hydrocarbons from worst-case credible spill scenarios. Modelling results indicated shoals relatively close to the release locations are at greatest likelihood of being impacts. These include Goeree Shoal, Eugene McDermott Shoals, Vulcan Shoal, Barracouta Shoals, Heywood Shoals and Echuca Shoals. In the unlikely event of a significant hydrocarbon spill, these benthic features may be contacted by entrained and dissolved hydrocarbons above impact thresholds. The shortest modelled time to contact was ≤ 4 hour, providing relatively little time for hydrocarbons to weather.

Studies of the shoals and banks in the region show these areas host biological communities distinct from the surrounding relatively deep bare sediment habitat (e.g. Heyward et al. 2017, 2012, 1997) indicated the banks were broadly similar. Each bank hosted a range of light-dependent ecosystems characterised by benthic primary producers, such as coral and macroalgae. Surveys of shoals near the Crux project following the Montara oil spill indicated these communities did not exhibit obvious impacts as a result of the spill (Heyward et al. 2013, 2012, 2010). However, considerable natural variation both over time and between locations was observed (Heyward et al. 2013). Reviews of the ecological function of the shoals and banks in the Timor Sea east of the project area concluded there is a relatively high degree of connectivity between shoals and banks, with the banks acting as a series of “stepping stones” (Heyward et al. 2017, 2013). In the event of a disturbance to benthic communities as the result of a hydrocarbon spill, the upstream shoals and banks may act as a source of propagules or larvae, which may enhance recovery.

Contact with dissolved and entrained hydrocarbons above adverse exposure thresholds may result in mortality of benthic biota. The loss of habitat-forming biota such as corals, macroalgae or sponges could result in changes to habitats, with consequent changes to fauna assemblages. As described above in **Benthic Communities**, impacts to corals, seagrasses and macroalgae include acute and chronic toxicity which may result in non-lethal impacts (e.g. reduced feeding) and mortality.

The time required for recovery following disturbance will depend on the nature and scale of the impact. Shoals and banks in the region have been exposed to significant intermittent disturbance for long periods of time, such as damage from cyclones and changes in water temperature associated with the El Niño-Southern Oscillation. Differences in benthic communities over time within and between shoals and banks (such as those observed by Heyward et al. 2013) may represent different phases of ecological succession.

*Offshore Reefs and Islands*

Several offshore reefs and islands were identified by the modelling study results as potentially being contacted by hydrocarbons above adverse exposure thresholds. These include Cartier Island, Ashmore Reef, Browse Island, Hibernia Reef, Scott Reef and Seringapatam Reef. These offshore islands and reefs often host biological communities that are distinct from coastal islands and the mainland. Like the **Shoals and Banks** described above, offshore reefs and islands typically host light-dependent ecosystems characterised by benthic primary producers. Potential impacts to submerged receptors associated with offshore reefs and islands will be similar to those described in **Shoals and Banks** above. Unlike shoals and banks, offshore reefs and islands may be exposed to floating hydrocarbons (in addition to entrained and dissolved hydrocarbons). While floating hydrocarbons from the Crux condensate release scenarios were not predicted to contact or accumulate on any offshore reefs or islands, stochastic modelling of the loss of vessel fuel scenario indicated a low probability of shoreline accumulation at several offshore islands and reefs, including the Bonaparte Archipelago, Bathurst Island and Browse Island.

The shorelines of offshore reefs and islands typically consist of intertidal reef flats and sandy beaches; shoreline types such as rocky shores, estuaries and mangroves typically do not occur. Given the modelling results estimated the minimum time to contact would be at least 144 hours for an emergent receptor (Hibernia Reef), any residual IFO reaching the shoreline of an offshore island or reef would be highly weathered. Stranding of floating oil on offshore islands and reefs may result in a band of weathered oil between the low- and high-water marks on shorelines and intertidal corals. This may result in impacts to fauna in these habitats, such as nesting turtles and wading birds. Refer to **Key Fauna Species** below for a discussion of potential impacts to these taxa.

*WA and NT Mainland Coastline*

The modelling studies identified potential shoreline contact along mainland Australian shores above the moderate shoreline exposure threshold for both the NT (Kakadu Coast, Cobourg Peninsula West Arnhem Land and Darwin Coast) and WA (Kimberley Coast). This was primarily from the loss of fuel from a vessel scenario, which comprised a fairly persistent hydrocarbon type (IFO). Minimum time to contact for these shoreline receptors ranged between 190 and 2,356 hours, indicating the IFO has considerable weathering time prior to reaching a shoreline.

*Key Ecological Features*

Modelling study results indicated several KEFs may be exposed to hydrocarbons above adverse impact thresholds (**Section 6.4.7**). KEFs with relatively high likelihoods of contact above impact thresholds include:

- ancient coastline at 125 m depth contour
- carbonate bank and terrace system of the Sahul Shelf
- continental slope demersal fish communities
- Ashmore Reef and Cartier Islands and surrounding Commonwealth waters
- Seringapatam Reef and Commonwealth waters in the Scott Reef complex, and
- pinnacles of the Bonaparte Basin.

All but two of these KEFs are entirely sub-tidal; discussion of potential impacts in this section is limited to sub-tidal features of the KEFs listed above. The exceptions of Ashmore Reef and Cartier Islands and surrounding Commonwealth waters and Seringapatam Reef and Commonwealth waters in the Scott Reef complex are considered above in **Offshore Reefs and Islands** and **Shoals and Banks**, respectively.

The sub-tidal KEFs may be exposed to entrained and dissolved above the adverse exposure thresholds. The environmental values of these sub-tidal KEFs are a function of their geomorphology and depth. A worst-case loss of well containment will not alter the geomorphology or depth characteristics of the sub-tidal KEFs. Given the nature of these KEFs (i.e. potentially more rugose and complex benthic habitats), there may be relatively diverse benthic communities associated with these habitats, such as filter feeding communities and demersal fish assemblages. These biological receptors may be impacted by dissolved and entrained hydrocarbon above adverse exposure thresholds, which may result in acute a or chronic toxic effects. KEFs are most likely to be contacted by the subsea loss of well control scenario, due to the large entrained hydrocarbon fraction. The sub-tidal KEFs are large environmental features. Modelling results indicated that no single deterministic run affected the entirety of a sub-tidal KEF; most runs typically affected a minor portion of any sub-tidal KEF. Given the nature of the KEFs and the scale of potential impacts, recovery of impacted parts of a KEF are expected to be facilitated by movement and recruitment of biota from the unaffected areas.

**Threatened Species and Ecological Communities**

*Key Fauna Species*

**Marine Mammals**

A range of cetaceans potentially occurring within the adverse exposure zones for the worst-case credible spill scenarios outlined in **Section 8.4.9.1**. These are described in **Section 6.5.5**. Cetaceans exposed to hydrocarbons may exhibit avoidance behaviour. Geraci (1988) documented apparent avoidance of floating by bottlenose dolphins, suggesting that cetaceans can detect and avoid surface slicks. However, observations during spills have recorded whales and dolphins traveling through and feeding in oil slicks. During the Deepwater Horizon spill cetaceans were routinely seen swimming in surface slicks offshore (and nearshore) (Aichinger Dias et al. 2017). Cetaceans observed during the spill response for the Montara oil spill included oceanic species such as false killer whales, bottlenose dolphins, spotted dolphins and spinner dolphins (Watson et al. 2009).

Cetaceans exposed to surface, entrained or dissolved aromatic hydrocarbons above adverse exposure thresholds may suffer external oiling, ingestion of oil and inhalation of toxic vapours (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016). Cetaceans in coastal waters (e.g. coastal dolphin species and humpback whales at the northern limit of their migration) are at lower risk of impacts than cetaceans in offshore water due to the oil weathering before reaching coastal waters. Impacts from direct oiling from a spill of Crux condensate are considered unlikely due to the non-persistent nature of the hydrocarbon and the thick layer of skin and blubber of cetaceans. Impacts from direct exposure are expected to be irritation of eyes and mucous membranes. Entrained hydrocarbons may be ingested by cetaceans during feeding, particularly by baleen whales. Some species of baleen whale, such as blue whales, may be seasonally present during their migrations. However, significant feeding during migration is not expected (although opportunistic feeding may occur).

Dugongs are known to occur in coastal waters and around offshore islands within the adverse exposure zones identified by the stochastic spill modelling. There is a paucity of studies examining the effects of hydrocarbon spills on dugongs, although the direct impacts of exposure to hydrocarbons may be similar to cetaceans. Like cetaceans, dugongs are expected to be resilient to direct impacts due to their thick skin and blubber. Suitable dugong habitat is associated with seagrass meadows, which are typically restricted to shallow waters around the mainland coast and islands. The distance of dugong habitat from the worst-case credible spill release locations means that oil reaching dugong habitat will be highly weathered.

#### Marine Reptiles

Stochastic modelling results indicated adverse exposure zones overlap the known distribution of several species of marine turtles and sea snakes. Saltwater crocodiles were also identified as potentially occurring within the adverse exposure zone; given the preferred habitat for salt water crocodiles are freshwater rivers and estuaries, impacts to this species from the worst-case hydrocarbon spills are not considered credible.

Marine turtles may be exposed to floating hydrocarbons when at the sea surface (e.g. breathing, basking etc.), and are not expected to avoid floating hydrocarbon slicks (NOAA 2010). Exposure to floating or entrained hydrocarbons may result in external oiling, which could result in impacts such as inflammation or infection (Gagnon and Rawson 2010l Lutcavage et al. 1995; NOAA 2010). Given the large portion of non-persistent hydrocarbons in Crux condensate, the loss of vessel fuel scenario is considered to pose the greatest risk of external oiling. Dissolved hydrocarbons may result in toxic effects on marine turtles, however their relatively impermeable skin reduces the potential for these impacts.

Several shoals and banks occur in the vicinity of the project area, which may be used as foraging areas by marine turtles (although none are recognised as BIAs). Impacts to benthic habitats and biota at these shoals and banks may result in a reduction of prey for marine turtles. Refer to **Shoals and Banks** above for further information on potential impacts to shoals and banks.

Stochastic modelling identified a number of shoreline habitats (sandy beaches and inter-nesting habitat) that may be exposed to hydrocarbons above adverse exposure thresholds. Many of these are classified as habitat critical for the survival of marine turtles in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017b). Significant breeding and nesting activity occurs at these locations throughout the region. Given the distance of these locations from the project area, worst-case credible spills of Crux condensate reaching these areas will be highly weathered and unlikely to result in impacts. The relatively persistent IFO from a worst-case loss of vessel fuel may result in shoreline accumulation on nesting beaches. Shorelines with the greatest potential for hydrocarbon accumulation were the Bonaparte Archipelago, Bigge Island, Joseph Bonaparte Gulf, the Kimberley Coast and Bathurst Island, all as a result of the loss of fuel from a vessel scenario. A spill reaching coastal waters during peak periods to turtle nesting may have increased potential to cause impacts. Nesting female turtles and hatchling turtles moving from the nest to the sea may be exposed to weathered IFO, potentially resulting in oiling. Given the highly weathered state of the oil, this is not expected to result in significant impacts.

Sea snakes have similar exposure pathways to spilled hydrocarbons as marine turtles (although sea snakes will not be exposed to shoreline hydrocarbon accumulation). Potential impacts are expected to be comparable and may include irritation of eyes and mucous membranes. Sea snake mortality has been linked to exposure to hydrocarbon spills, with dead sea snakes recovered from the region of the Montara oil spill showing high levels of petroleum hydrocarbons (including PAHs) in the trachea, lungs and stomach (Gagnon 2009). These results are consistent with exposure through ingestion and respiration of hydrocarbons. Ashmore Reef and Hibernia Reef are noted as being one of the few sites where the critically endangered leaf-scaled sea snake and short-nosed sea snake have been recorded, along with other species of sea snake. Both the leaf-scaled and snort-nosed sea snakes have not been detected at Ashmore Reef since 2001, despite increased biological survey effort. Both locations were identified by the stochastic modelling as potentially being exposed to hydrocarbon above adverse exposure limits.

**Birds**

A number of seabird and migratory shorebird species have been identified as potentially occurring within the adverse exposure zone for the worst-case hydrocarbon spill scenarios contains. Additionally, a number of BIAs for several seabird and migratory shorebird species occur throughout the adverse exposure zone, centred around offshore and coastal islands and mainland shorelines.

Spill of Crux condensate are unlikely to pose a significant risk due to the non-persistent nature of the condensate, however a worst-case IFO spill may result in a considerable mass of persistent floating oil. Seabirds and migratory birds are particularly vulnerable to contact with floating hydrocarbons, which may mat feathers. This may lead to hypothermia from loss of insulation and ingestion of hydrocarbons when preening to remove hydrocarbons; both impacts may result in mortality (Hassan and Javed 2011).

Seabirds may encounter floating oil when foraging for food. Seabird foraging is typically concentrated around roosting locations, such as offshore and coastal islands. Potential roosting locations lie considerable distances from the project area; the nearest significant roosting location is Cartier Island, which lies approximately 105 km from the proposed Crux platform location. Ashmore Reef is a Ramsar-listed wetland and hosts significant seabird colonies and is an important stopping area for migratory shorebirds. Ashmore Reef lies approximately 155 km from the proposed Crux platform location. Floating hydrocarbons reaching these locations would be significantly weathered. Seabirds typically nest above the high-water mark and as such, are not likely to encounter stranded hydrocarbons.

Migratory shorebirds are seasonally abundant during summer months, and a spill during this period would have greater potential to impact migratory shorebirds. Migratory shorebirds are not likely to encounter floating oil at sea, but may be affected by shoreline accumulation of oil, or oil and shallow foraging habitats such as intertidal mudflats. Unlike seabirds, shorebird mortality due to hypothermia from matted feathers is relatively uncommon (Henkel et al. 2012). Indirect impacts, such as reduced prey availability and bioaccumulations of PAHs, may occur (Henkel et al. 2012).

**Fish**

Fish respire through gills, which may make them more vulnerable to dissolved hydrocarbon fraction that fauna with less permeable skins, such as cetaceans, marine reptiles and birds. Despite this apparent vulnerability, fish mortalities are rarely observed to occur because of hydrocarbon spills (Fodrie and Heck 2011; International Tanker Owners Pollution Federation 2011b), although instances of fish mortality from spills in confined areas (e.g. bays) have been recorded. These observations are consistent with fish moving away from hydrocarbons in the water (Hjermann et al. 2007). Stochastic modelling results indicated that hydrocarbons are likely to be concentrated in surface waters. As a result, demersal fish are unlikely to be directly affected unless near a subsea release, as these are likely to be associated with seabed features (e.g. **Shoals and Banks** and **Ecological Features**). Pelagic fish are more likely to encounter dissolved and entrained hydrocarbons above adverse exposure thresholds but are may move away from affected areas.

Exposure of fish to hydrocarbons may results in acute and chronic effects and may vary depending on a range of factors such as exposure duration and concentration, life history stage, inter-species differences and other environmental stressors (Westera and Babcock 2016). Environmental monitoring of pelagic and demersal fishes immediately following the Montara oil spill indicated that fish were exposed to hydrocarbons, although no adverse effects were detected (Gagnon and Rawson 2012, 2011). Further sampling and testing over time indicated that fish captured in close proximity to the Montara wellhead were comparable to those collected from reference sites (Gagnon and Rawson 2012, 2011).

Most marine fish species produce very high numbers of eggs, which then undergo a planktonic larval development phase. Early life history stages of fish (planktonic eggs and larvae) may be more vulnerable to hydrocarbon pollution than juvenile and adults, as these early life history phases cannot actively avoid water with high concentrations of hydrocarbons. Fish embryos and larvae may exhibit genetic and developmental abnormalities from long-term exposure to low concentrations of hydrocarbons (Fodrie and Heck 2011), although such long exposures may not be representative of real world conditions. PAHs have also been linked to increased mortality and stunted growth rates of early life history (pre-settlement) of reef fishes, as well as behavioural impacts that may increase predation of post-settlement larvae (Johansen et al. 2017). Given the temporal and spatial scale of the worst-case credible spill scenarios (as shown by a single deterministic run), and the typically high supply of eggs and larvae, it is unlikely that any of the worst-case credible spill scenarios will result in significantly reduced recruitment of fish due to impacts during early life history phases. This conclusion is supported by studies of fish stocks following large-scale hydrocarbon spills, which have shown relatively little evidence of reduced recruitment at the scale of fish stocks/populations (Fodrie and Heck 2011).

**Shark and Rays**

Transitory and resident sharks may occur within the adverse exposure zones identified by the stochastic spill modelling. Whale sharks may occur within the project area (e.g. traversing the project area during migration to and from aggregation off Ningaloo Reef) and a BIA for foraging whale sharks overlaps with the project area. Tagging studies by Meekan and Radford (2010) have shown whale sharks traversing the Timor Sea following the seasonal aggregation off the Ningaloo Coast. Whale sharks may be exposed to entrained and dissolved hydrocarbons by contact with their gills and ingestion during feeding. The large volume filter feeding behaviour of whale sharks may result in a relatively high potential for exposure to entrained hydrocarbons compared to many other marine species (Campagna et al. 2011).

Tagging studies off Ningaloo Reef have shown that whale sharks disperse broadly (Meekan and Radford 2010; Wilson et al. 2006). Genetic studies of whale sharks have shown low genetic diversity, which suggests flow of genetic material through the movement of individual sharks over large spatial scales (Schmidt et al. 2009). On this basis, only a portion of the whale shark population in the Timor Sea would be within the area above the adverse exposure threshold at any one time and impacts such as toxic effects leading to mortality would be expected to affect a small number of individual animals.

Other oceanic (e.g. mako) and resident (e.g. reef) sharks will occur throughout the adverse exposure zone, although Heyward et al. (2017) noted that shark numbers were lower than expected, potentially due to fishing pressure. Potential impacts to other oceanic shark species are likely to be similar to fish (see **Fish** above). Any reduction of shark numbers may take longer to recover due to the relatively long lifespans and low reproductive output compared to finfish species.

**Socio-economic and Cultural Environment**

*World Heritage*

A small portion of the Kakadu World Heritage Area, approximately 806 km from the proposed Crux platform location, was overlapped by the floating, dissolved and entrained hydrocarbons above the moderate adverse exposure threshold from the loss of well containment and loss of vessel fuel scenarios. Modelling results indicate the likelihood of contact above adverse exposure thresholds was very low; the potential contact was at very low concentrations. No shoreline accumulation above adverse exposure thresholds was predicted to occur. On the basis of the nature and scale of the contact predicted by the modelling, no impacts to the world heritage values of the Kakadu World Heritage Area will occur.

*National Heritage Places*

The Kakadu National Heritage Place has the same extent at the Kakadu World Heritage Area discussed above in **World Heritage**; no impacts to the heritage values of the Kakadu National Heritage Place will occur as a results of a worst-case credible hydrocarbon spill.

Spill modelling results indicated that the shorelines of the West Kimberley National Heritage Place may be contacted by floating, accumulated, entrained and dissolved hydrocarbons above impact thresholds. The West Kimberley National Heritage Place contains a range of shoreline types, including rocky shores, sandy beaches and mangroves. Potential impacts to these are discussed above in **WA and NT Mainland Coastline**. Many of the heritage values of the West Kimberley National Heritage Place (refer to **Section 6.6.5**) lie inland and will not be impacted by a hydrocarbon spill. The modelling study results indicate probabilities of shoreline accumulation above the moderate adverse accumulation threshold within the West Kimberley and Kakadu National Heritage Places are very low, 1.8% and 0.6% respectively. The maximum modelled shoreline accumulation of spilled oil on both the West Kimberley and Kakadu National Heritage Place coastlines are < 45 g/m$^2$.

*Commonwealth Heritage Places*

Several offshore islands and reefs listed as Commonwealth Heritage Places were identified by the spill modelling results as potentially being contacted by hydrocarbons. These include:

- the Ashmore Reef National Nature Reserve Commonwealth Heritage Place
- Scott Reef and Surrounds Commonwealth Heritage Place, and
- Mermaid Reef – Rowley Shoals Commonwealth Heritage Place.

The heritage values of these reefs are primarily their outstanding natural values. Refer to **Offshore Reefs and Islands** above for a discussion of potential impacts to these natural values.

*Ramsar Wetlands*

Several Ramsar sites were identified in the results of the spill modelling studies as potentially being impacted by spilled hydrocarbons. Most of these are in the far-field of the model and are highly unlikely to be contacted by hydrocarbons above the moderate adverse exposure thresholds. The exception is Ashmore Reef, which is the closest Ramsar site to the project area. The migratory bird species associated with Ramsar sites are most vulnerable to floating oil, and oil accumulations along the shoreline. All four credible worst-case scenarios were identified as potentially resulting in shoreline accumulation at Ashmore Reef, however the likelihoods for contact by floating hydrocarbon sis very low (≤ 2.4%). Potential impacts of spilled hydrocarbons on migratory shorebirds are discussed above in **Key Fauna Species**; refer to this section for further information.

Note the Protected Matters search tool report identified several Ramsar wetlands at Christmas Island, however given the distance to these receptors these Ramsar wetlands will not credibly be impacted.

*Marine Parks*

Modelling results of the worst-case credible spill scenarios indicated a range of Commonwealth, state and territory marine parks may be contacted above adverse exposure thresholds (**Table 8-48**). These parks contain a range of environmental values such as marine biota, representative marine habitats and unique sea scapes (e.g. KEFs). Environmental values for these marine parks are described in **Section 6.6.8** and discussed above in **Physical Environment**, **Ecosystems, Communities and Habitats**, and **Threatened Species and Ecological Communities**. Refer to these sections for discussion of potential impacts to these environmental values within marine parks.

*Cultural Heritage*

Aboriginal people have a long history of inhabitation across northern Australia, particularly coastal regions. As outlined above in **WA and NT Mainland Coastline**, potential shoreline contact above adverse exposure thresholds may occur. Hydrocarbon pollution and shoreline clean-up activities may result in disturbance to culturally significant sites. Given the nature of the worst-case credible spill scenarios, the potential for shoreline accumulation above which clean-up activities would be effective is very low.

*Marine Archaeology*

No impacts to marine archaeological features will occur because of a worst-case credible hydrocarbon spill. The nearest historic shipwreck, the Anne Millicent, lies approximately 108 km from the proposed Crux platform location.

*Commercial Fisheries*

A number of commercial fisheries operate within the adverse exposure zone determined from spill modelling results. The worst-case credible hydrocarbon spill scenarios may result in a range of impacts to commercial fishing activities, such as (International Tanker Owners Pollution Federation 2011b):

- displacement of fishing effort from areas affected by a spill or spill response activities
- damage to fish stocks due to mortality
- closure of fisheries by management agencies
- inability to sell catch due to perceived or actual fish tainting or contamination, and
- oiling of fishing gear, particularly by floating oil.

A significant hydrocarbon spill would likely result in the temporary closure of areas of fisheries within the area of adverse exposure. The spatial extent and duration of the closure would depend on the nature and scale of the pollution resulting from the hydrocarbon spill. Given the large spatial extent of managed fisheries in the area potentially contacted above adverse exposure thresholds, a spill is unlikely to result in complete closure of a fisher. Rather, the closure of areas to fishing is more likely to result in the displacement of fishing effort. Displacement from productive fishing areas may result in impacts to fishers such as increased costs and reduced catch per unit effort.

Exposure of fish to hydrocarbons may result in tainting, which may render landings unsuitable for human consumption. Tainting may occur even a low levels of hydrocarbon exposure. Monitoring of fish for taint immediately following capping of the Montara well detected differences between fish likely to have been exposed to hydrocarbons, however these differences were not conclusively linked to oil contamination and fell within the range of “normal” fish odours (Rawson et al. 2011). Samples collected at the same monitoring locations two and four months after were not distinguishable (Rawson et al. 2011). These results are consistent with other studies of fisheries resources exposed to hydrocarbon pollution, which acknowledge the potential for impacts to fisheries resources and have shown little potential risk for consumers if suitable fisheries management actions are undertaken (Law and Hellou 1999; Law and Kelly 2004).

Fish caught in areas affected by a significant hydrocarbon spill may be perceived as being of poorer quality, even if no decrease in quality is evident. This may result in lower prices at the time of sale and subsequently lead to reduced income for commercial fishers.

*Traditional Indonesian Fishing*

Traditional Indonesian fishing activity occurs within the MoU box, which overlaps the export pipeline corridor and lies within the adverse exposure zones identified by the spill modelling results. Traditional fishing is concentrated around banks, shoals, island and reefs; refer to **Shoals and Banks** and **Offshore Reefs and Islands** for discussion of potential impacts to these receptors. The worst-case credible spill scenarios may impact upon the biological resources exploited by traditional Indonesian fishers, such as fish and benthic invertebrates (e.g. sea cucumbers and trochus shells). Impacts to these biological resources may result in effects on traditional fishers, such as reduced catch rates and displacement of fishing effort. Given the distance between the release locations and the reefs exploited by traditional Indonesian fishers, impacts to traditional Indonesian fishing activities are considered to be unlikely and would be minor.

*Tourism and Recreation*

There are currently no known tourism activities in the project area, or surrounding areas, due to the remoteness of the area. Some tourism activity tourism activities may occur at the remote offshore islands and reefs within the adverse exposure zones. These activities are expected to be exclusively nature-based tourism and impacts to the environmental values associated with these islands and reefs may impact upon tourism activities. Refer to **Offshore Reefs and Islands** for discussion on the potential impacts to these receptors.

Mainland coastline and islands will typically host more nature-based tourist activities than offshore islands. This activity is expected to be seasonal, with increased visitation during the winter dry season months. Refer to **WA and NT Mainland Coastline** above for a discussion of potential impacts to the natural receptors along these coastlines.

Impacts to tourism activities are expected to be minor based on the likelihood and nature of contact to environmental values that support tourism activities. Impacts to these values may result in displacement of tourism activity, and potentially minor loss of revenue for tourist operators (e.g. charter fishing cancellations due to fishery closures).

*Military/Defence*

Defence activities within the offshore NAXA are unlikely to be affected by the worst-case credible hydrocarbon spills. Activities may be temporary displaced from areas where spill response operations are underway. This would be highly localised and temporary in nature.

*Ports and Commercial Shipping*

Potential impacts to ports and commercial shipping from the worst-case credible spill scenarios are expected to be very minor and consist of temporary displacement of other users from areas where spill response activities are underway. These are expected to be concentrated around the release location.

*Offshore Petroleum Exploration and Operations*

Petroleum activities in the region include the Shell-operated Prelude FLNG facility, the INPEX-operated Ichthys facility and the Montara development (previously operated by PTTEP Australia, now Jadestone Energy). Other exploration activities are expected to occur in the Timor Sea throughout the life of the Crux project. Reduction in water quality as a result of a worst-case credible spill may affect the operation of these facilities if seawater at the facility is no longer suitable for intake (e.g. for use as cooling water or feed water for RO water generation). This may result in impacts to routine operations such as decreased production. A worst-case hydrocarbon spill response may result in competition for vessels and potentially drilling rigs (if well intervention or a relief well is required).

*Indonesian and Timor-Leste Coastlines*

The spill modelling results indicated there is the potential for several worst-case credible spill scenarios resulting in contact with the Indonesian and Timor-Leste coastlines above the moderate adverse exposure thresholds. The likelihood of contact was very low except for the entrained fraction from the worst-case well blowout scenario. The likelihood of this fraction contacting the Indonesian and Timor-Leste coastlines above the moderate entrained adverse exposure threshold were 17.1% and 14.7% respectively. Minimum times to contact were 28.2 days and 30.8 days for Indonesian and Timor-Leste respectively. Given the relatively long time to contact, soluble aromatic hydrocarbon fractions are unlikely to be present, leaving relatively low toxicity residual hydrocarbons such as paraffins. Potential impacts may include smothering of coastal infrastructure (e.g. aquaculture, fishing equipment), which may result in localised economic impacts.

### 8.4.9.4 Risk and Impact Summary and Key Management Controls

Table 8-49: Unplanned Spills Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Unplanned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Significance | Likelihood | Residual Impact |
| **Evaluation – Unplanned Risks** | | | | | | | |
| Unplanned risks resulting from a worst-case credible spill scenario from:<br>• loss of well control<br>• loss of process storage tank containment<br>• loss of containment from export pipeline, and<br>• loss of fuel from vessel. | X | X | X | X | Massive | Remote | Major |
| ***Key Management Controls*** | | | | | | | |
| Vessel specific controls will align with MARPOL 73/78, the *Navigation Act 2012,* the *Protection of the Sea (Prevention of Pollution from Ships Act 1983* and subsequent Marine Orders (as appropriate for vessel classification), which includes managing spills aboard, emergency drills and waste management requirements.<br>All vessels involved in the project will have a valid Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan (as appropriate for vessel classification) which is maintained including: Spill Kit – Pollution Control Equipment container/ box is located at a strategic location, containing adequate equipment/material (minimum as per the Shipboard Oil Pollution Emergency Plan) to control spills of pollutants on board.<br>All project vessels operating within the project area will adhere to the navigation safety requirements contained within the COLREGS, Chapter 5 of the SOLAS Convention, STCW Convention, the *Navigation Act 2012* and any subsequent Marine Orders, which specify standards for crew training and competency, navigation, communication, and safety measures.<br>Offshore Vessel Inspection Database or equivalent reviewed prior to mobilisation of project vessels. | | | | | | | |

| |
|---|
| Australian Hydrographic Service notified of location of installed infrastructure to facilitate inclusion on nautical charts.<br>Australian Hydrographic Service advised of project activities and installed infrastructure to facilitate issuing Notices to Mariners.<br>Accepted WOMP in place for all wells, in accordance with the OPGGS Act requirements. The WOMP will outline the barriers in place throughout the construction and operation of the well to prevent a loss of well control. For development drilling, the WOMP will include:<br>• maintaining overbalance in the well through the use of weighted drilling fluids,<br>• installation of a BOP during drilling operations of the bottom hole sections, and<br>• regular testing of BOP.<br>Accepted EPs and OPEPs in place for all petroleum activities appropriate to the nature and scale of the credible hydrocarbon spill risks. The OPEP include an Operational and Scientific Monitoring Program will be initiated and implemented as appropriate to the nature and scale of the spill and the existing environment, as informed by a net environmental benefit assessment. The OPEP shall consider:<br>• relief well planning and preparedness<br>• interim source control (e.g. capping stacks for subsea well blowouts)<br>• oiled wildlife response, and<br>• operational and scientific monitoring.<br>Stakeholder consultation throughout the Crux project, including consultation consistent with the requirements of the OPGGS (E) Regulations for all subsequent petroleum activities and associated EPs.<br>Where vessel dynamic positioning systems are required[30], they shall be in working order whilst within the Crux platform petroleum safety zone at all times.<br>Development and implementation of a maintenance management system for the Crux platform, export pipeline and subsea infrastructure.<br>Development of simultaneous operations (SIMOPS) plans where interactions with other activities (e.g. Prelude operations, backfill installations) may credibly occur.<br>Concrete coating of the majority of the export pipeline reduces the risk of a dropped object damaging the pipeline.<br>The Crux platform will have controls/systems in place that will assist with the early detection of spills/leaks from the NNM platform, including:<br>• fire and gas system,<br>• satellite monitoring of the Crux platform location, and<br>• continuous process control monitoring system (assist in detection of significant leaks).<br>Assess feasible design and monitoring controls that will assist with the early detection of spills/leaks from the Crux platform. Controls that are considered compatible with the NNM philosophy will be implemented, unless it can be demonstrated that the 'cost' is grossly disproportionate to the benefit gained.<br>Selection of key material will take corrosion into account.<br>Pigging of the Crux gas export pipeline will be undertaken as required throughout operations to detect defects, assess integrity and enable risk based management of the pipeline.<br>Fuel type will be considered in the construction vessel contracting process where alternatives to marine diesel are being considered. |

### 8.4.9.5 Acceptability of Impacts and Risks

The acceptable levels of impact for the receptors that may credibly be impacted or at risk from the unplanned spills aspect of the Crux project are summarised in **Table 8-50**. The

[30] The requirement for DP will be determined based on the activities the vessel will be undertaking and Shell's operational requirements. There may be instances where a Shell vessel operating within the petroleum safety zone does not require DP (e.g. environmental surveys away from the platform and subsea infrastructure).

method by which these acceptable levels were determined, along with a justification as to why these are acceptable, are discussed in **Section 7**.

In addition to the receptor-based acceptable levels of impact listed in **Table 8-50**, Shell considers any event that results in, or has the potential to result in, the unplanned release of Crux condensate or vessel fuel to be unacceptable.

Based on the outcomes of the evaluation of impacts and risks, Shell considers that the residual environmental risks of the unplanned spill aspect of the Crux project are acceptable.

Further discussion of the acceptability considerations outlined in **Section 7** in relation to the unplanned spills aspect of the Crux project is provided below.

Table 8-50: Acceptable Levels of Impacts and Risks from Unplanned Spills

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| Physical environment | Water quality | No significant impacts to water quality during the Crux project. | Yes. Shell considers large-scale releases of hydrocarbons during the Crux project to be unacceptable. Such spills have potential to result in significant environmental impacts. Consequently, Shell will apply its considerable experience and knowledge in the offshore petroleum industry to ensure such a release during the Crux project never occurs.<br>Shell has applied a conservative approach to the identification and modelling of the credible worst-case hydrocarbon spills. This information was used to inform the evaluation of the environmental impacts and risks, and is consistent with the precautionary principle.<br>Shell will implement industry standard controls to manage the risk of unplanned hydrocarbon spills. The EPs for activities undertaken as part of the Crux project are required to have an Oil Pollution Emergency Plan (OPEP) commensurate to the nature and scale of the hydrocarbon pollution risks for the activity. |
| | Sediment quality | No significant impacts to sediment quality during the Crux project. | |
| Ecosystems, communities and habitats | Benthic communities | No significant impacts to benthic habitats and communities.<br>Impacts to non-sensitive benthic communities limited to a maximum of 5% of the project area. | |
| | Shoals and banks | No direct impacts to named banks and shoals.<br>No loss of coral communities at named banks or shoals as a result of indirect/offsite[31] impacts associated with the Crux project. | |
| | Offshore reefs and islands | No impacts to offshore reefs and islands. | |
| | WA and NT mainland coastline | No impacts to WA and NT mainland coastline. | |
| | Key Ecological Features | No significant impacts to environmental values of KEFs. | |
| Threatened species and ecological communities | Marine mammals | No mortality or injury of threatened or migratory MNES fauna from the Crux project.<br>Management of aspects of the Crux project must be aligned to conservation advice, recovery plans and threat abatement plans published by the DoEE.<br>No significant impacts to threatened or migratory MNES fauna. | |
| | Marine reptiles | | |
| | Birds | | |
| | Fish | | |
| | Sharks and rays | | |
| Socio-economic | Commonwealth Marine Area | No significant impacts to the Commonwealth marine area | |

[31] As defined in the Matters of National Environmental Significance - Significant impact guidelines 1.1 (DoE 2013a).

| Receptor Category | Receptor Sub-category | Acceptable Level of Impact | Are the Crux Project's Impacts and Risks of an Acceptable Level? |
|---|---|---|---|
| and cultural environment | | beyond 1 km from the Crux platform or drilling locations. | |
| | World Heritage Properties | No impacts to world heritage values. | |
| | National Heritage Places | No impacts to national heritage values. | |
| | Commonwealth Heritage Places | No impacts to Commonwealth heritage values | |
| | Declared Ramsar Wetlands | No impacts to ecological values of Ramsar wetlands | |
| | Marine Parks | No impacts to the values of marine parks | |
| | Commercial fisheries | No negative impacts to exploited fisheries resource stocks which result in a demonstrated direct loss of income. | |
| | Traditional Indigenous fishing | No negative impacts to exploited fisheries resource stocks. | |
| | Tourism and recreation | No negative impacts to nature-based tourism resources resulting in demonstrated loss of income. | |

**Principles of ESD**

The risks and impacts from the worst-case credible spill scenarios are inherently inconsistent with some of the principles of ESD based on the following:

- environmental resources may be significantly impacted in the event a worst-case credible spill occurs, and
- a worst-case credible spill may prevent others exercising their right to access environmental resources.

Shell will apply a range of controls to ensure that a worst-case credible spill from the Crux project never occurs. These include a range of industry best practices that have been developed through extensive industry experience, including the lessons learned from significant unplanned releases such as the Macondo and Montara well blowouts. Following successful application of these controls, Shell considers the residual risk to be consistent with the principles of ESD. This consistency is achieved by:

- developing natural resources in an environmental responsible manner, resulting in income for government, generation of Australian jobs, and developing an increased understanding of the Timor Sea environment.
- application of the precautionary principle in the assessment of hydrocarbon spill scenarios by:
  - using worst-case credible spill scenarios. Industry statistics indicate the vast majority of unplanned spills are significantly smaller than the worst-case credible spills.

- using a stochastic modelling approach for numerical modelling of the worst-case credible spill scenarios that includes a large number (300) of deterministic runs covering a range of metocean conditions, and
- using environmentally conservative adverse exposure zone thresholds.

**Relevant Requirements**

Management of the impacts and risks from unplanned hydrocarbon spills are consistent with legislative requirements, including:

- compliance with international maritime conventions, including:
  - STCW Convention
  - SOLAS Convention
  - COLREGS, and
  - MARPOL:
    - Annex I: prevention of pollution by oil and oily water.
- compliance with Australian legislation and requirements, including:
  - *Navigation Act 2012* and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*:
    - Marine Order 21 (Safety of Navigation and Emergency Procedures
    - Marine Order 27 (Radio Equipment)
    - Marine Order 30 (Prevention of Collisions)
    - Marine Order 71 (Masters and Deck Officers), and
    - Marine Order 91 (Marine pollution prevention – oil).
  - OPGGS (E) Regulations:
    - an accepted OPP for the Crux project
    - accepted WOMPs for all well activities, including drilling, operation, suspension and abandonment, and
    - accepted EPs and OPEPs for all petroleum activities associated with the Crux project.
- Implementation of recognised industry best practices, such as:
  - use of BOPs while drilling over-pressured formations with potential for flow, including regular function and pressure testing of the BOPs
  - design, construction and operation of Crux infrastructure in accordance with recognised industry standards
  - mutual aid agreement in place with other petroleum operators to assist with drilling rig availability for relief well drilling
  - agreements in place with oil spill response service providers;
  - leak detection system on export pipeline to detect major incidents, and
  - development of SIMOPS plans for activities that may interact with the Prelude FLNG facility.

**Matters of National Environmental Significance**

A worst-case hydrocarbon spill may result in significant impacts for several MNES. Shell will put in place a range of measures during all phases of the Crux project to ensure that spills of hydrocarbons that may result in significant impacts to threatened and migratory species do not occur. Shell considers the residual risk to these MNES to be acceptable, after application of the key management controls proposed in this OPP.

*Threatened and Migratory Species*

The evaluation of impacts and risks indicates that significant impacts to threatened and migratory species may occur in the event of a significant hydrocarbon spill. Pollution from hydrocarbon spills is recognised as a threat in management plans, recovery plans and conservation advice for a number of threatened and migratory species. Alignment of the Crux project with these documents is provided in **Table 8-51**.

*Wetlands of International Importance*

While considered very unlikely due to the distance from the Crux project area, results from the stochastic spill modelling studies indicated hydrocarbons above impact thresholds may contact the Ramsar wetland at Ashmore Reef.

*Commonwealth Marine Environment*

The evaluation of impacts and risks indicates that significant impacts to the Commonwealth marine environment may occur in the event of a significant hydrocarbon spill. The potential for widespread impacts to water quality may result in a number of marine species to be affected.

Table 8-51: Summary of Alignment of the Risks and Impacts from Unplanned Spills from the Crux Project with Relevant Requirements for EPBC Threatened Fauna

| Sensitivity | MNES Acceptability Considerations (Significant Impact Guidelines, EPBC Management Plans/Recovery Plans/Conservation Advices) | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| Marine mammals | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Unplanned spills | Shell has identified the potential for hydrocarbon pollution, and potential consequential habitats degradation, from large-scale hydrocarbon releases as a significant environmental risk. Shell has applied a range of controls that are intended to reduce the likelihood of such a release occurring, and mitigative controls to understand and reduce the severity of impacts should such as release occur. Large-scale hydrocarbon releases pose a significant safety risk for Shell personnel, and considerable effort will be applied to the Crux project design to reduce the inherent likelihood of large-scale hydrocarbon releases occurring. |
| | Conservation management plan for the blue whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth of Australia 2015a) | Pollution (persistent toxic pollutants) | |
| | Conservation advice *Balaenoptera borealis* sei whale (DoE 2015c) | | |
| | Conservation advice *Balaenoptera physalus* fin whale (DoE 2015d) | | |
| | Conservation management plan for the southern right whale: A recovery plan under the *Environment Protection and Biodiversity Conservation Act 1999* (DSEWPaC 2012) | | |
| Marine reptiles | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Unplanned spills | |
| | Recovery plan for marine turtles in Australia (Commonwealth of Australia 2017b) | Chemical and terrestrial discharge | |
| | Conservation advice on short-nosed sea snake (*Aipysurus apraefrontalis*) (DSEWPaC 2010a)<br>Conservation advice on leaf-scaled sea snake (*Aipysurus foliosquama*) (DSEWPaC 2010b) | Degradation of reef habitat | |
| Birds | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Unplanned spills | |
| | Wildlife conservation plan for migratory shorebirds (Commonwealth of Australia 2015b) | Oil spills<br>Modification of habitat from pollution | |

| Sensitivity | EPBC Management Plans/Recovery Plans/Conservation Advices | Threats Relevant to the Project | Demonstration of Alignment as Relevant to the Project |
|---|---|---|---|
| | National recovery plan for threatened albatrosses and giant petrels 2011-2016 (DSEWPaC 2011) | | |
| | Conservation advice for *Sternula nereis* (fairy tern) (DSEWPaC 2011b) | | |
| | Conservation advice *Numenius madagascariensis* eastern curlew (DoE 2015i) | | |
| | Conservation advice *Calidris ferruginea* curlew sandpiper (DoE 2015h) | | |
| | Conservation advice *Anous tenuirostris melanops* Australian lesser noddy (DoE 2015j) | | |
| | Conservation advice *Calidris canutus* red knot (DoE 2016a) | | |
| | Conservation advice *Calidris tenuirostris* great knot (DoE 2016b) | | |
| | Conservation advice *Charadrius leschenaultii* greater sand plover (DoE 2016c) | | |
| | Conservation Advice *Charadrius mongolus* lesser sand plover (DoE 2016d) | | |
| | Conservation advice *Limosa lapponica menzbieri* bar-tailed godwit (northern Siberian) (DoE 2016e) | | |
| Sharks and rays | Significant impact guidelines for Critically Endangered, Endangered, Vulnerable and Migratory species (**Table 7-1**) | Unplanned spills | |
| | Conservation advice *Rhincodon typus* whale shark (DoE 2015l) | Habitat disruption from mineral exploration, production and transportation | |
| | Recovery plan for the white shark (*Carcharodon carcharias*) (DSEWPaC 2013a) | Habitat modification/ degradation | |
| | Sawfish and river shark multispecies recovery plan (Commonwealth of Australia 2015c) | | |
| **Sensitivity** | **EPBC Management Plans/Recovery Plans/Conservation Advices** | **Threats Relevant to the Project** | **Demonstration of Alignment as Relevant to the Project** |

| | | | |
|---|---|---|---|
| | Approved conservation advice for *Glyphis glyphis* (speartooth shark) (DoE 2014c) | | |
| | Approved conservation advice for *Pristis clavata* (dwarf sawfish) (DEWHA 2009b) | | |
| | Approved conservation advice for *Pristis zijsron* (green sawfish) (DEWHA 2008b) | | |
| Commonwealth marine environment | Significant impact guidelines for Commonwealth marine environment (**Table 7-1**) | Unplanned spills | |

**Internal and External Context**

Shell's ongoing consultation program will consider statements and claims made by stakeholders when undertaking the assessment of impacts and risks. Shell has also considered the internal context, including Shell's environmental policy and ESHIA requirements. The environmental performance outcomes, and the controls which will be implemented, are consistent with the outcomes from stakeholder consultation for the Prelude FLNG facility and Shell's internal requirements.

Shell has, and will continue to maintain, an appropriate spill response framework, which includes regular testing of the response arrangements. This response framework will be applied to all stages of the Crux project.

**Acceptability Summary**

The assessment of impacts and risks from the worst-case credible unplanned hydrocarbon spills determined the residual impact and risk rating is Major (**Table 8-49**). Given the significant consequence of the risks associated with these worst-case hydrocarbon spills, Shell has undertaken an extensive, conservative risk assessment and will apply a range of controls consistent with relevant requirements and industry best practice. As outlined above, the acceptability of the impacts and risks from unplanned spills associated with the Crux project has been considered in the context of:

- ESD
- relevant legislative requirements
- external context (i.e. stakeholder claims), and
- internal context (i.e. Shell requirements).

Based on the points discussed above, Shell considered the impacts and risks from worst-case unplanned spill scenarios from the Crux project to be acceptable following the application of the controls outlined in **Table 8-49.**

#### 8.4.9.6 Environmental Performance Outcomes

No emergency events[32] associated with the unplanned release of Crux condensate or vessel fuel to the marine environment during the Crux project.

### 8.4.10 Cumulative Impacts

#### 8.4.10.1 Project Context

This section provides a summary of cumulative impacts considered to be of primary relevance to the Crux project, as appropriate to the early stage evaluation of impacts and risks to be considered at an OPP level of assessment. Given the low likelihood of unplanned events that may arise during the Crux project (e.g. large hydrocarbon spills), unplanned events have not been considered in the assessment of cumulative impacts.

The preceding assessments in **Sections 8.4.1** to **8.4.9** inclusive, have addressed the interaction of the Crux project aspects with the receiving environment on a single-aspect basis. This section builds on those assessments and takes into account the potential for cumulative or additive effects to occur.

As described previously in **Section 6.6.16**, the nearest facility in proximity to the Crux project include the Montara FPSO facility located approximately 36 km north of the Crux platform. The Ichthys Project offshore facilities are located approximately 164 km to the

[32] Emergency events are incidents which result in the mobilisation of the Shell emergency response team.

south-west of the proposed Crux platform, and the Prelude FLNG facility is approximately 165 km to the south-west of the Crux platform, representing the location where the export pipeline will feed into.

### 8.4.10.2 Description and Evaluation of Impacts

The potential for cumulative impacts resulting from the Crux project were considered from two perspectives:

- How might aspects from the Crux project compound with aspects of existing activities within the Timor Sea region? This focussed on the potential interactions with other oil and gas developments, including Prelude, Ichthys and Montara.
- How might an environmental receptor be affected by multiple aspects of the Crux project and other activities? This approach is receptor-based and differs from the aspect-based approach applied in **Sections 8.4.1** to **8.4.9**.

The cumulative impact assessments are presented below.

**Aspect-based Cumulative Impacts**

The aspects-based cumulative impact assessment considers how the aspects from the Crux project, and the associated environmental impacts, may interact with aspects from other activities in the region to result in increased environmental impacts. Other activities identified included:

- the Prelude FLNG facility
- the Montara production facility
- Ichthys offshore production facility, and
- commercial shipping.

The aspects identified that were common to these activities and the Crux project were:

- physical presence and vessel movements
- light emissions
- atmospheric emissions, and
- liquid discharges.

Each of these are considered in the sections below.

*Physical Presence and Vessel Movements*

Interactions with other marine users are considered remote, given the relatively minor physical scale of the project, combined with the relatively low level of activity within the open offshore waters of the project area, the potential cumulative impact of offshore petroleum safety zones restricting commercial fishing areas is understood. The petroleum safety zones associated with offshore projects are spatially small (typically 500 m radius) compared to the area available to commercial fisheries, and therefore not expected to represent a large area of displaced fishing effort relative to the available fishing zones.

The physical presence of Crux project facilities/infrastructure and vessels will not have a cumulative impact on marine fauna as it represents a small physical footprint in the context of an open marine environment where marine fauna transit the region.

Vessel movements will be associated with all stages of the Crux project, which is geographically separated from the Montara, Ichthys or Prelude facilities. There is pre-existing marine vessel traffic, including support vessels at the existing operational facilities. The potential environmental impacts associated with vessels are considered to be largely similar for offshore oil and gas developments in terms of interactions with marine fauna and planned emissions and discharges.

The majority of the vessel movements will be within the vicinity of each project's facilities/infrastructure and equipment. The movement of vessels related to the Crux project will be contained within the in-field development area and the pipeline corridor, with transit to/from nearest port as required. Therefore, overlap of each project's vessel movements in the offshore marine environment is considered unlikely with typical industry navigational practice. Given the broad marine area and the open shipping navigational areas available for vessels in the offshore Browse Basin, this potential for impact 'in-field' is very low. Therefore, cumulative impacts at a local scale from associated with the project in combination with other activities are low. There may be a minor cumulative impact associated with the concurrent transit movement of vessels between Broome and/or Darwin to Crux and other offshore destinations, which may be experienced in or near to the ports of Broome or Darwin. This will be subject to normal marine operational practice of shipping coordination and interface with the respective port authorities and marine users. Therefore, the potential for significant cumulative impact from physical is low.

*Light Emissions*

Light emissions will be associated with the Crux project, albeit at relatively low levels given the NNM operational philosophy. Given the relative proximity of the Montara FPSO facility (approximately 36 km to the north) and taking into consideration the results of the light impact assessment, there may be some overlap in light emissions from the projects. As presented in **Section 8.4.2**, the extent of light propagation at ambient conditions may theoretically extend up to approximately 38 km, which are comparable to a moonless clear night. This may lead to an incremental increase in light emissions predominantly over open ocean waters, with potential for very slight additive increases at Goeree Shoal or Vulcan Shoal, these representing submergent receptors with limited influence from atmospheric light. However, these cumulative increases are expected to be minimal and are therefore not expected to have a significant cumulative impact on marine fauna.

*Atmospheric Emissions*

The evaluation of the atmospheric emissions relevant to the Crux project was previously provided in **Section 8.4.4**. In a cumulative context for atmospheric emissions impact to air quality, the determinable impacts are localised around the Crux project. There are no facilities within the In-field Development Area for which cumulative impacts to the local environment can be considered.

In respect of cumulative GHG emissions and the broader species and ecosystems effects it is appreciated that the generation of emissions arising from offshore developments are to be considered in the context of cumulative contributions. This is achieved by the legal framework in Australia which requires the emissions profiles of individual projects, such as the Crux project, to be assessed individually for their broader effects. It is important to note these projects are subject to the same legislative and policy frameworks to manage emissions as Crux. It is through compliance with these frameworks that the emissions from the Crux project, and other projects in Australia are managed to within acceptable levels.

*Liquid Discharges*

Planned discharges to the marine environment, such as PFW water, drill cuttings and fluids and wastewater, will be associated with the Crux project, with limited potential to interact with other users or facilities. Conservative modelling of the planned discharges for the Crux project predicted that the discharges would be below ANZECC & ARMCANZ guideline thresholds within a radius of approximately 1 km from the discharge location (**Section 8.4.8**). Planned discharges from the Montara FPSO facility, as the nearest facility to the in-field development area, are localised and expected to disperse rapidly within close proximity to discharge points, with no expected cumulative effect from liquid discharges overlapping across the projects' area of influence. The Montara facility PFW discharges are regulated in accordance with the conditions of approval (EPBC 2002/755) under the EPBC Act, and associated Operations Environment Plan approvals by NOPSEMA. The in-field development area is an open ocean environment, within a localised impact zone as informed by modelling studies, and geographically from the nearest shoals/banks and other nearest offshore facilities.

A monitoring program will be established to verify that concentrations of planned discharges will meet relevant ANZECC & ARMCANZ guidelines (or within natural variation or background concentration) beyond the predicted mixing zone(s). Considering this, no significant cumulative impacts from planned discharges of PFW and other liquid discharges are expected.

**Receptor-based Assessment of Cumulative Impacts**

*Water Quality*

Water quality was identified as being impacted by the following aspects:

- physical presence and vessel movements, and
- liquid discharges.

As outlined in **Section 8.4.1**, the potential for impacts to water quality from the physical presence and vessel movements aspect are negligible and predominantly occur during the development drilling and construction phases of the project. Water quality will recover from impacts from the physical presence and vessel movement aspects rapidly following completion of the activity. Hence the potential for impacts to water quality from this aspect to interact with other aspects is very limited.

**Section 8.4.8** described the discrete impacts of the liquid discharge streams that will occur during the Crux project. Many of these are separated temporally or spatially, and hence have negligible potential to interact.

Wastewater and cooling water discharges from vessel are typically small volumes and have relatively low potential for impacts. Given the Crux platform will be NNM, wastewater discharges from the platform will also be negligible. These liquid discharges have negligible potential to interact with other aspects and hence will not result in significant cumulative impacts.

PFW is a large volume continuous discharge during the operational phase of the Crux project. Given this discharge will only occur during the operational phase, it will not interact with other liquid discharges that have considerable potential for impacts to water quality, such as drilling fluids, cuttings and hydrotest water which are limited to discrete activity phases.

Based on the consideration of the potential interactions between aspects of the Crux project that may impact upon water quality, the cumulative impacts are of an acceptable level. Refer to **Section 7** for additional information on the acceptable level of impact to water quality.

*Sediment Quality*

Sediment quality was identified as being impacted by the following aspects:

- physical presence and vessel movements, and
- liquid discharges.

As outlined in **Section 8.4.1**, the potential for impacts to sediment quality from the physical presence aspect are negligible and predominantly occur during the development drilling and construction phases of the project. The presence of Crux project infrastructure may encourage the deposition, and inhibit the re-suspension, of fine sediments. Fine sediments have a greater surface are to volume ratio and have greater potential to bind potential contaminants such as metals, which are retained in situ. This modification of sedimentary processes may limit the transport of contaminated sediments. It may also result in elevated levels of contaminants in close proximity to potential contaminant sources (e.g. PFW discharge and drill cuttings at the Crux platform location).

The liquid discharges with the greatest potential to impact sediment quality are the discharges of PFW and drilling fluids/cuttings at the Crux platform location. While these activities will not occur simultaneously, the drill cuttings from the foundation wells will remain in situ around the Crux platform. Hence the potential sediment contamination from PFW discharges during the operational phase may result in cumulative impacts to sediment quality. The discharged cuttings at the Crux platform location are expected to have relatively low concentrations of potential contaminants based on the drilling related controls Shell will implement (preference to WBM, no whole SBM discharge, residual SBM < 10% by weight averaged over all sections using SBM). Modelling studies of the PFW plume indicate that it will dilute and mix prior to contacting the seabed, hence the potential for direct interaction with the PFW and the sediments at the base of the Crux platform is not considered credible. Suspended solids arising from the produced water (e.g. solids discharged in the PFW, precipitates formed by dissolved components of the PFW) are expected to be very fine. These fine sediments will have low settling velocities and will be advected away from the discharge location by the currents at the discharge location and are unlikely to be deposited in the area around the platform.

While there is the potential for sediments arising from the discharge of treated PFW to be deposited on top of sediments contaminated by drilling fluids and cuttings, the potential cumulative impacts are not expected to exceed the impacts outlined in the evaluation of impacts from liquid discharges (**Section 8.4.8**). This is based on the following points:

- sediment contamination from drilling fluids and cuttings will be concentrated at the Crux platform and tieback drilling locations.
- sediment contamination is expected to be low based on the controls implemented by Shell.
- the PFW plume will not interact directly with the sediments, and
- solids from the PFW stream are expected to be fine, and advected away from the discharge location by water movement.

Based on the consideration of the potential interactions between aspects of the Crux project that may impact upon sediment quality, cumulative impacts will be of an acceptable level. Refer to **Section 7** for additional information on the acceptable level of impact to sediment quality.

*Benthic Communities*

Benthic communities (excluding shoals and banks, which are considered separately below) were identified as being impacted by the following aspects:

- physical presence and vessel movements
- underwater noise, and
- liquid discharges.

Benthic communities at the base of the Crux platform will be impacted by the physical presence of the construction of the platform, the discharge of drilling fluid and cuttings, and the ongoing discharge of treated PFW from the platform. The impacts of these aspects of the activity will combine to result in cumulative impacts to benthic communities. The potential for significant cumulative impacts will be limited to the vicinity (i.e. < 100 m) from the Crux platform. The benthic habitats around the Crux platform are characterised by soft sediments with low density epifaunal communities. These are widely represented in the region, are not particularly sensitive.

Benthic habitats and communities along the export pipeline route will be modified by the presence of the pipeline. However, given the majority of the pipeline route is not in close proximity to other sources of impacts (e.g. Crux platform and Prelude FLNG), the potential for cumulative impacts is negligible.

The continental slope demersal fish communities KEF lies within pipeline route but is distant from the Crux platform location (approximately 73 km). Shell is not aware of any other activities that have, or credibly will, impact upon the environmental values of this KEF in the Timor Sea; the Prelude, Ichthys and Montara production facilities all lie beyond the KEF and the area is not currently subject to trawl fishing activities. Cumulative impacts from the Crux project on the KEF are not considered credible.

IMR activities that have the potential to impact upon benthic habitats, such as span rectification if required, will be infrequent and highly localised; cumulative impacts from these activities are considered to be negligible.

The drilling of wells will result in disturbance of the seabed from the mooring anchors for the MODU, which will directly disturb the seabed at the anchoring locations. The seabed disturbance from the anchors will recover over time as natural sedimentary processes fill in the holes created by the anchors after they are removed. This disturbance has a negligible potential for cumulative impacts to benthic communities.

Underwater noise impacts are most likely to occur during piling and VSP, as these activities will generate high intensity noise that may propagate considerable distances. Other noise sources (e.g. vessel-related noise) have a low potential for impacts to benthic communities. The benthic communities in the Crux project area are not considered to be particularly sensitive to noise-related impacts and the activities that generate high intensity noise are of relatively short duration (i.e. hours to days). No other high intensity noise sources within the vicinity of the Crux project area have been identified, with noise from other operating petroleum facilities expected to have no potential for impact within the Crux project area. The potential for the underwater noise aspect of the Crux project to contribute to cumulative impacts to benthic habitats is negligible.

The benthic communities within the vicinity of the planned hydrotest discharge will already be impacted by the construction and operation of the Prelude FLNG facility. These benthic communities are also of low sensitivity and are broadly represented in the region. The hydrotest discharge is a one-off impact that is expected to dilute rapidly. The hydrotest water plume will not reach benthic habitats associated with the banks and shoals or the continental slope demersal fish communities KEF. Given the non-persistent nature of the impacts from the discharge of hydrotest water, the potential for hydrotest water to result in cumulative impacts is negligible.

Based on the consideration of the potential interactions between aspects of the Crux project that may impact upon benthic communities, the cumulative impacts are of an acceptable level. Refer to **Section 7** for additional information on the acceptable level of impact to benthic communities.

*Shoals and Banks*

Sediment quality was identified as being impacted by the following aspects:

- underwater noise

- light, and
- liquid discharges.

The distance of the Crux platform from shoals and banks within the Crux in-field development area, along with Shell's implementation of a 1 km buffer around the shoals within which no activities will occur, means that cumulative impacts to banks and shoals are unlikely.

With the exclusion of VSP during the drilling of tieback wells in close proximity to banks and shoals, underwater noise impacts to banks and shoals are considered to be very unlikely due to the distance of these environmental receptors from the Crux platform. Noise from piling is unlikely to significantly impact the communities, although the 24-hour TTS threshold for fish may be exceeded at Goeree Shoal if a relatively heavy hammer is required for piling. As this impact is temporary, any fish impacted are expected to recover. VSP may be undertaken during drilling of tieback wells, which will result in acoustic emissions to the marine environment, however modelling studies indicated these would not exceed impact thresholds for fish, cetaceans or marine turtles (SVT 2018). Any tieback wells will be at least 1 km from the boundary of the shoals within the Crux in-field development area. Other activities that may impact upon the shoals (e.g. light and VSP noise from a MODU drilling a tieback well) will not occur simultaneously with piling; tieback wells are not expected to be required for a number of years after initial production commences from the Crux foundation wells.

Given the distances of potential light and liquid discharge sources from banks and shoals (> 13 km for the Crux platform, > 1 km for any tieback wells), these aspects will not credibly impact upon the biota of the banks and shoals. Results from modelling studies of drilling fluids and cuttings discharges indicated that impacts from sediment deposition will be limited to > 326 m (RPS 2018a). Suspended sediment plumes from drilling will not exceed impact thresholds at > 1 km (i.e. the buffer distance around the shoals). Hence cumulative impacts exacerbated by light or liquid discharges will not credibly occur.

Based on the consideration of the potential interactions between aspects of the Crux project that may impact upon shoals and banks, cumulative impacts will be of an acceptable level. Refer to **Section 7** for additional information on the acceptable level of impact to shoals and banks.

*Threatened Species and Ecological Communities*

A number of threatened and migratory under the EPBC Act were identified as potentially occurring within the Crux project area. These were identified as being impacted by the following aspects:

- physical presence and vessel movements
- underwater noise
- light
- waste management, and
- liquid discharges.

Migratory species are of particular concern when assessing cumulative impacts, as impacts to habitats critical to the survival of the species that are distant from the Crux project area may make them more vulnerable. For example, loss of critical nesting and foraging habitats for migratory birds that nest in east Asia may make these species more vulnerable to impacts in their migratory corridors.

The planned impacts to threatened from the Crux project are very low, and do not exceed the significant impact triggers for threatened and migratory species outlined in **Section**

**7**. Where applicable, aspects of the Crux project are aligned to conservation advice, threat abatement plans, and recovery plans published by the DoEE. As such, cumulative impacts to threatened and migratory species from planned impacts from the Crux project are not considered credible.

Based on the consideration of the potential interactions between aspects of the Crux project that may impact upon threatened and migratory species that are MNES, cumulative impacts to will be of an acceptable level. Refer to **Section 7** for additional information on the acceptable level of impact to threatened and migratory species that are MNES.

#### 8.4.10.3 Conclusion

The project will not result in any material cumulative impacts to the marine environment at a local scale as there is no significant overlap with other existing facilities. No cumulative impacts to key values and sensitivities are expected. Therefore, the residual impact rankings detailed in the previous aspect assessments (**Sections 8.4.1** to **8.4.9** inclusive) remain unchanged.

Regional cumulative impacts may occur in terms of incremental increases in vessel movements and $CO_2$ emissions. However, these have been assessed as minor and do not change the residual impact rankings for any of the potential impacts assessed in this OPP.

The potential cumulative impacts to environmental receptors are low and will be largely restricted to the waters, sediment and benthic habitats and communities in the immediate vicinity of the Crux platform. Potential cumulative impacts, both aspect- and receptor-based, were all determined to be within the acceptable levels defined in **Section 7**.

### 8.4.11 Health Impacts

#### 8.4.11.1 Project Context

This section assesses the potential public health impacts of the Crux project on local communities relevant to the socio-economic environment. The anticipated health impacts associated with the Crux project with potential to affect any onshore communities, in particular the onshore logistics bases of Broome and Darwin, are expected to be very minor with due consideration of:

- the remote offshore context for this project. The majority of construction and operation activities are well offshore, 620 km from Broome and approximately 700 km from Darwin.
- the logistical arrangements for transiting workers aims to minimise overnight stays in onshore locations, and seeking to utilise existing established supply chain logistics now in place for Prelude FLNG, and
- existing industrial areas will be utilised for bases in Broome and/or Darwin.

#### 8.4.11.2 Description and Evaluation of Impacts and Risks

The project presents a number of potential hazards that may have occupational health consequences for workers if not managed appropriately. In particular, the potential for exposure to hazardous materials, equipment, air emissions and excessive noise levels which could result in injury or fatality. These occupational health risks do not extend to onshore communities due to the significant distance of the Crux project from coastal communities. Similarly, the Crux project is distant from other facilities, such as Prelude or Montara, therefore interaction effects for considerations such as air emissions or noise amenity are not realistic, although there may be potential for noise from aircraft/helicopters in Broome in support of project personnel transfers. The risks to workers associated with the project and the appropriate workplace health and safety arrangements are addressed through Shell's Occupational, Health and Safety policies and procedures, and NOPSEMA/WorkSafe requirements (e.g. through Safety Case and occupational health and safety commitments). While fundamentally important to maintain positive health and wellbeing, occupational health and risk impacts are not within the scope of this OPP document for the evaluation of environmental impacts/risks.

**Community Health Services**

Onshore projects, in particular during construction, typically have some local impact on healthcare facilities and services. This is usually due to project drawing on the local healthcare system to meet worker needs for, among other things, health checks, medical examinations and vaccinations. Given the offshore nature of the Crux project, with relatively low personnel requirements compared to onshore gas facilities, this demand will be much less for the Crux project as onshore construction activities are limited.

Workers that cannot be adequately treated offshore will be brought to the nearest onshore health facility for treatment. Local healthcare services could also be called upon in the event of an emergency or non-routine event such as a serious offshore incident involving multiple workers requiring immediate medical treatment; however, the likelihood of this is low, and given the low personnel requirements for the project and the typical industry arrangements to be well equipped in emergency response arrangements for offshore operations, this is unlikely to present a significant demand on existing community services. In the event of a significant emergency, some additional external resources may need to be drawn on.

Given the offshore context, community interaction with the Crux project will be limited. The use of health facilities and services such as doctors, dentists, chemists and hospital beds by the onshore workforce in Broome or Darwin is likely to be minimal as only a small number may need to access local health facilities and services during their roster and while travelling to and from the facility. Offshore Fly-In Fly-Out workers are not expected to be in the local onshore communities for any length of time and are unlikely to seek elective healthcare services locally. The social receptors that could be affected by additional demands on community health services are the local onshore communities, tourists visiting the area and regional communities. In the event of a major non-routine event requiring major assistance, the Royal Flying Doctor Service, General Practitioners, paramedics and other local healthcare professionals will be called upon as required to respond to the situation at the time.

Should a non-routine event occur, access for Broome and/or Darwin residents to both regular and emergency health services could be reduced. The effects of the service reduction would be limited in duration but could be highly disruptive for local residents and service providers. Shell's Emergency Planning will therefore include early discussions with local health authorities on arrangements for triage, coordination of emergency response and maintenance of health services for local residents. Community health impacts associated with the Crux project are expected to be of minor magnitude for routine activities, and hence the significance has been assessed to be minor.

**Workforce Influx Pressures**

The Crux project will result in the increased presence of workers in Broome and/or Darwin, with a commensurate increase in the number of vessel/helicopter movements to/from the town, which will vary depending on the stage of project development.

There is potential for a 1–2-year peak period during peak construction. It is reasonably expected that the Broome community will experience some increased presence (including probably overnight stays) of Fly-In Fly-Out project workers during this peak construction phase. During steady state operations, there will be personnel transfers to Crux platform, which is expected to be preferentially by vessel via the Prelude FLNG facility. It is anticipated that there will be short-term intermittent increases associated with planned maintenance, for example during shutdowns (40 POB).

The addition of a project workforce has potential to contribute to existing pressures on public health capacity in the local communities. In the context of the Crux project, as an offshore project with minimal workforce requirements associated with the NNM operational philosophy, Shell is not anticipating significant impacts on this context. Shell is committed to building on the existing local supply chain logistics and arrangements that are now established with Prelude, in a manner that minimises disturbance to local communities and supports local content where practical. This includes, for example, the intent to replicate the arrangements for flights in/out of Broome to be scheduled in accordance with the Broome International Airport Fly Neighbourly Policy, which will also support the objective to minimise social amenity disturbance from intermittent noise.

### 8.4.11.3 Risk and Impact Summary and Key Management Controls

Table 8-52: Public Health Evaluation of Impacts and Risks

| Project Component/ Activity | Environmental Value/Sensitivity | | | | Evaluation – Planned | | |
|---|---|---|---|---|---|---|---|
| | Physical Environment | Threatened Species and Ecological Communities | Ecosystems, Communities and Habitats | Socio-economic and Cultural Environment | Magnitude | Sensitivity | Residual Impact |
| **Evaluation – Planned Impacts** | | | | | | | |
| Planned impacts resulting from the Crux project, including:<br>• effects on community health services, and<br>• workforce influx pressures | | | | X | Minor effect | Low | Minor |
| ***Key Management Controls*** | | | | | | | |
| An ongoing stakeholder engagement program will be undertaken as the project progresses through future phases of development planning and implementation.<br>Emergency Planning will include early discussions with local health authorities on local community arrangements to provide appropriate support in the scenario of medical response.<br>The Crux platform is designed to operate under a NNM concept, which will deliver benefits of minimal workforce requirements and commensurate minimal disturbance to onshore communities<br>Scheduling of flights in accordance with the Broome International Airport Fly Neighbourly Policy.<br>Shell will aim to replicate Prelude planned flight considerations (flight plans/times), which are designed to minimise local disturbance:<br>• No flights on Sundays<br>• Reduced number of flights on Saturday, and<br>• Flying route to avoid Roebuck Bay and local Aboriginal community (Mallingbar).<br>Shell is considering local content and progressing an AIP plan as part of the development of the Crux project. | | | | | | | |

### 8.4.11.4 Acceptability

Shell Australia's activities are governed in full alignment with the Shell General Business Principles. Key to these principles is that Shell employees share a set of core values – honesty, integrity and respect for people. Key principles include:

- local communities – Shell aims to be a good neighbour by continuously improving the ways in which we contribute directly or indirectly to the general wellbeing of the communities within which we work. We manage the social impacts of our business activities carefully and work with others to enhance the benefits to local communities, and to mitigate any negative impacts from our activities. In addition, Shell companies take a constructive interest in societal matters, directly or indirectly related to our business.

- communication and engagement – Shell recognises that regular dialogue and engagement with stakeholders is essential. In our interactions with local communities, we seek to listen and respond to them honestly and responsibly. Part of this commitment is ensuring those people and organisations that are impacted by our activities are engaged, and that their concerns are heard and responded to.

It is through this process of open engagement and dialogue, with strong emphasis on HSSE & SP governance through the Shell Control Framework, that public health impacts are demonstrably managed as core business to be acceptable and appropriate to the offshore context of the Crux project.

The residual impacts and risks are minor. Shell considers residual impacts of minor or lower to be acceptable if they meet legislative and Shell requirements. The discussion above demonstrates that these requirements have been met in relation to human health aspects of the Crux project.

Based on the points discussed above, Shell considered the impacts and risks from health impacts relevant to the Crux project to be acceptable.

Shell will continue to assess and manage community health impacts associated with the Crux project throughout the asset's life. There is no proposed environmental performance outcome proposed to manage the low level of inherent community health impact associated with the project.

# 9 Environmental Performance Framework

## 9.1 Introduction

This section of the OPP presents an Environmental Performance Framework for the Crux project. The purpose of this framework is to demonstrate Shell's delivery mechanism for the commitments made in this OPP and outline the monitoring that will be undertaken throughout project execution.

As presented in **Section 8**, EPOs have been developed in line with NOPSEMA's definition of an EPO as a "*measurable level of performance required for the management of environmental aspects of the project to ensure that the environmental impacts are risks will be of an acceptable level*" (NOPSEMA 2018a).

Given the intent of an OPP as an early stage, 'whole-of-project' approvals document, the EPOs defined for the Crux project are appropriately high-level, with a focus on the key environmental outcomes to be achieved commensurate to the impact/risk conclusions in **Section 8**. These will be proceeded by EPOs which are further refined for the purpose of developing activity-specific EPs, at which stage further definition of environmental risks, impacts and controls will be available.

The Environmental Performance Framework specific to the Crux project has been developed in line with Shell's HSSE & SP Policy (**Section 3**), principles of ESD and the relevant legislative requirements, codes, standards and guidelines available at this time (**Section 2**). Future activity-specific EPs will incorporate any contemporary changes to these requirements, codes, standards and guidelines, applicable at the time of the specific activity.

## 9.2 Environmental Acceptability

Through the impact and risk evaluation process presented in **Section 8**, the conclusions of acceptability are drawn with reference to the consideration of:

- all practicable measures have been identified commensurate with the risks and impacts
- internal context – the proposed controls and residual risk level are consistent with Shell policies, procedures and standards
- external context – consideration of the environment consequence and stakeholder expectations, and
- other requirements – the proposed controls and residual risk level are consistent with national and international standards, laws and policies.

The specific EPOs, and corresponding Key Management Controls, for each aspect are summarised in **Sections 8.4.1** to **8.4.11** inclusive, and are therefore not repeated in this section.

The key management controls will provide evidence of compliance and ensure EPOs are achieved and will be carried into the activity-specific EPs as defined in this early-stage OPP. Regular checks and performance reviews will be undertaken during the life of the project to ensure performance is maintained at each stage of the project.

Shell has considered the principles of ESD, as defined in Section 3A of the EPBC Act:

- decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations

- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- the principles 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 conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making, and
- improved valuation, pricing and incentive mechanisms should be promoted.

A summary of the Crux project, with regard to the Principles of ESD, is provided in **Table 9-1**.

Table 9-1: Summary of the Crux Project with Regard to the Principles of ESD

| Principle of ESD | Project Alignment |
|---|---|
| Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations. | The evaluation presented in this OPP, as a whole-of-project life assessment, takes into account both short-term and long-term considerations and potential impacts and risks as relevant to the Crux offshore context.<br>Specifically, alignment of the project with this principle is demonstrated with regard to:<br>• Shell's HSSE & SP Management Framework, which mandates HSSE & SP principles and expectations for all assets throughout the project life-cycle<br>• Provision of gas to support the continued operation of Prelude FLNG, is an important transitional fuel to meet regional and global demand for energy in a sustainable framework, with significant contribution to Government taxation revenue, creation of employment opportunities and economic growth. |
| 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 (i.e. the precautionary principle). | An evaluation of all impacts and risks associated with the Crux project has been undertaken within this OPP (**Section 8**) and key management controls defined as relevant to the nature and scale of the potential impacts/risks. The assessment has acknowledged any specific areas where there may be some level of uncertainty (i.e. confidence), and this has been taken into account when defining the potential impacts and risks and residual risk rating.<br>The assessment has been informed by a detailed marine baseline studies program and understanding of the marine environment (**Section 6**). The evaluation has also been informed by modelling, which has a number of levels of conservatism built in to take into account uncertainty in final project design. |
| 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 key management controls and EPOs, as presented in this OPP have been defined with consideration of this principle.<br>The Crux project will ultimately provide source of gas for the continued operation of the Prelude FLNG facility, in an environmentally responsible manner to support intergenerational equity and stewardship. |
| The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making. | The conservation of biological diversity and overall ecosystem integrity has been considered in the systematic evaluation of relevant impacts and risks (**Section 8**) to derive a conclusion of acceptability, and has been informed by a detailed understanding of the existing environment (**Section 6**) within the project area and wider area of influence.<br>The key management controls and EPOs, as presented in **Section 8**, have also been defined with consideration of this principle. |
| Improved valuation, pricing and incentive mechanisms should be promoted. | The key management controls, including the governing requirements embedded in Shell's HSSE & SP Control Framework, align with this principle, where practicable and relevant to this Crux project context. |

## 9.3 HSE-MS Implementation and Review

### 9.3.1 Introduction

Shell manages all HSSE & SP aspects in accordance with the Shell Group Health, Security, Safety and Environment Policy (**Figure 3-1**). The Shell HSSE & SP-MS Manual is applicable to all Shell business groups and governs the effective management of these aspects and the implementation and review of environmental performance, as described in **Section 3.3** and further detailed in the following sections.

### 9.3.2 Contractor HSSE Management Process

Throughout the Crux project lifecycle contractors and sub-contractors will complete project related activities on behalf of Shell. Shell's HSSE & SP Control Framework (outlined in **Section 3**) contains the HSSE & SP requirements that apply to every Shell company, contractor and joint venture under Shell's operational control.

To ensure integrity, health and safety risks are effectively managed throughout the contract lifecycle, and for all contracted activities, Shell implements pre- and post-contract award processes in line with the Shell HSSE & SP Control Framework. Several key contractor HSSE & SP management processes are listed in **Table 9-2**.

A post contract award gap assessment may also be performed between Shell's HSSE & SP Control Framework and each contractor's plan for completeness.

Table 9-2: Key Shell Pre- and Post-Contract Award Processes

| Pre-Contract Award Activities | Post-Contract Award Activities |
|---|---|
| • Appointing a competent Contract Owner and Contract Holder for each contract<br>• Assess contract HSSE & SP risk and contract mode: Identifying the HSSE &SP risks associated with the contracted activities and defining how to manage the risks<br>• During the bid evaluation, assessing whether the contractor has the capability and resources to manage the HSSE & SP risks, through HSSE & SP prequalification assessments (green-banding)<br>• Before contract award, confirming that the contractor meets requirements. Focus on closing gaps in draft contract HSSE & SP Plan submitted by contractor<br>• Defining the contractor HSSE key performance indicators<br>• Defining the level of Company monitoring based on the capability of the contractor and the contract HSSE & SP risk | • Verifying that the contractor and its personnel have been informed of the HSSE & SP requirements of the contract<br>• Verifying that the contractor manages the HSSE & SP requirements of the contract and review and approve the Contract HSSE & SP Plan when it is required<br>• Monitoring and regularly assessing the HSSE & SP performance of the contractor<br>• Regularly reviewing the management of risks in contracted activities |

### 9.3.3 Competency Requirements and Assurance

It is the responsibility of each contractor to assure the competence of their personnel, and to ensure that their personnel have the appropriate level of competence required to safely and effectively carry out their work.

Competence Assurance Plans aligned with Shell training requirements will be developed for the Crux project. These Competence Assurance Plans will ensure contractor personnel records are maintained in a centralised manner and kept up-to-date with regard to personnel qualifications and experience.

### 9.3.4 Environmental Audits and Assurance

The Shell HSSE & SP MS Manual provides a structured and documented framework for the implementation, monitoring and reporting of HSSE compliance. Project specific Annual HSSE Plans stipulate the timing of environmental audits and reviews to be undertaken. This includes contractor HSSE audit, waste management audit/review, gap analyses against HSSE Control Framework Manuals, and compliance audits against EPs and this OPP.

To assure the functionality of the HSSE & SP MS as a whole, intermittent Shell Group audits are also undertaken across all Shell businesses. The results of these audits feed back into the process in the form of corrective actions that inform the improvement process. Corrective actions are monitored and reviewed through to completion. Assurance for the Crux platform will be executed as per an annual HSE assurance plan.

### 9.3.5 Management of Incidents and Non-Conformances

The Shell Australia HSSE Incident Reporting, Investigation and Follow up process governs the management of all HSSE incidents. For the purpose of this process, non-conformances are treated and referred to in the same manner as incidents. All employees and contracted staff are encouraged to submit incident reports such that all incidents may be successfully entered in the incident recording system.

Dedicated HSE Business Performance Reviews also require the number of incidents to be reported to Shell Group on a quarterly basis in accordance with the Shell Group (PMR standard.

### 9.3.6 Emergency Preparedness and Response

#### 9.3.6.1 Spill Response

**Oil Pollution Emergency Plan**

An OPEP is an operational document which outlines the processes to be followed to effectively respond in the event of an unplanned release of hydrocarbons resulting from project activities. NOPSEMA (2018d) requires that an OPEP includes "*adequate arrangements to ensure that titleholders can implement oil pollution response control measures in a timely manner and for the duration of the activity.*"

Commensurate to this, an OPEP details the actions to be undertaken in response to an incident, the hierarchy for command, control and communication, and the emergency specialist response groups, statutory authorities and other relevant external bodies required for interface.

An integrated Crux – Prelude OPEP will be developed. The OPEP will incorporate a spill impact mitigation assessment which will assess the potential environmental benefit and detriment associated with each relevant spill scenario, and an ALARP assessment.

The OPEP will be tailored to the nature and scale of the hydrocarbon spill, providing situational awareness which is critical to an effective spill response. As per Regulation 14 (8A) of the OPGGS (E) Regulations, Shell will conduct a desktop and/or field-based test of OPEPs.

**Operational and Scientific Monitoring Program**

An OSMP will be developed as required by NOPSEMA to be deployed in the event of a hydrocarbon spill. The OSMP is crucial in determining the extent, severity and persistence of any impacts resulting from a hydrocarbon spill. The OSMP may also be used to determine the effectiveness of the spill response (OPEP), and inform future OPEPs and spill response, and enable an assessment of environmental performance.

The Shell OSMP will comprise a number of scientific and operational monitoring plans, as well as an implementation plan, which will serve to guide spill response and assess potential environmental impacts. It is expected that the existing OSMP framework, as established for Prelude, will be reviewed and extended as appropriate to accommodate Crux.

Shell has a number of existing alliances with service providers and businesses within the industry which may be leveraged in the event of a hydrocarbon spill. These will be reviewed and incorporated into the development of an OSMP.

### 9.3.7 Monitoring and Measurement of Emissions, Discharges and Environment Quality

Emissions and discharges from the Crux platform and ambient environment quality will be monitored on an ongoing basis.

**Sections 5.7** and **8.4** provide a description of the emissions and discharges associated with the Crux platform and whole of life-cycle activities, and the relevant key controls to achieve ALARP. The monitoring frequency of key discharges and emissions are further summarised in **Table 9-3**. The specific parameters to be monitored and recorded will be further refined as the project progresses.

Table 9-3: Summary of Discharge and Emission Monitoring

| Monitoring Program | Objectives | Indicative Frequency |
|---|---|---|
| *Marine Discharges* | | |
| Crux platform monitoring<br><br>Environment monitoring (water, quality, sediments and benthic habitats) | To understand impacts from the discharge of PFW from the Crux platform to inform if further action is required in order to meet the relevant EPO on an ongoing basis | Continuous monitoring, whilst available, of PFW discharge volume (online flow meter) and dispersed oil-in-water (online oil-in-water analyser)<br>Chemical characterisation of PFW<br>Additional monitoring as a result of trigger actions<br>Periodic environment monitoring within the in-field development area. |
| WET testing | To characterise operational PFW discharges and to inform triggers appropriate to the relevant local environmental receptors (e.g. benthic communities) | Initially when a suitably representative PFW sample of normal operations could be taken, and then on a risk-based approach thereafter. |
| *Atmospheric Emissions* | | |
| GHG emissions<br>(e.g. from flaring, fuel gas and diesel combustion, and fugitive emissions) | To record and report emissions as required by the *National Greenhouse and Energy Reporting Act 2007* and the Safeguard Mechanism* | Ongoing to inform annual submission of NGER reports* during the operational stage of the project |
| Criteria pollutant emissions (e.g. from flaring, fuel gas and diesel combustion, and fugitive emissions) | To record and report emissions as required by the *National Pollutant Inventory** | Ongoing to inform annual submission of NGER reports* during the operational stage of the project |

* Or in accordance with any relevant contemporary requirements at the time of activity.

The monitoring programs detailed in **Section 8.4** and summarised in **Table 9-3** for emissions and discharges, will form the basis of adaptive management frameworks developed for inclusion in activity-specific EPs. These frameworks will be consistent with a whole-of-project adaptive environmental management approach which will allow tailored management as the project progresses.

Adaptive management will allow adjustment in the relevant monitoring programs should more suitable monitoring approaches become available or sampling indicates contaminants are trending toward levels in exceedance of the relevant performance standards. The adaptive management framework will enable Shell to consistently manage risks and impacts to acceptable levels. The circular nature of the adaptive management framework will also enable further understanding and management of the environmental impacts related to project activities.

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## 10.2 List of Acronyms

| Acronym | Definition |
|---|---|
| ABS | Australian Bureau of Statistics |
| ADB | Asian Development Bank |
| AFMA | Australian Fisheries Management Authority |
| AFZ | Australian Fishing Zone |
| AGRU | Acid Gas Removal Unit |
| AIMS | Australian Institute of Marine Science |
| AIP | Australian Industry Participation |
| ALARP | As Low as Reasonably Practicable |
| AMOSC | Australian Marine Oil Spill Centre |
| AMP | Australian Marine Park |
| AMSA | Australian Maritime Safety Association |
| ANSD | Australian National Shipwrecks Database |
| ANSI | American National Standards Institute |
| ANZECC & ARMCANZ | Australian and New Zealand Environment and Conservation Council and Agricultural and Resource Management Council of Australia and New Zealand |
| APPEA | Australian Petroleum Production and Exploration Association |
| ARP | Applied Research Program |
| BIA | Biologically Important Area |
| BoM | Bureau of Meteorology |
| Bonn Convention | Convention of the Conservation of Migratory Species of Wild Animals 1979 |
| BOP | Blowout Preventer |
| BRUV | Baited Remote Underwater Video Station |
| BTEX | Benzene, Toluene, Ethylbenzene and Xylene |
| BWM | The International Convention for the Control and Management of Ships' Ballast Water and Sediments |
| CAMBA | Agreement Between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and Their Environment 1986 |
| CAPEX | Capital Expenditure |
| CCS | Carbon Capture and Storage |
| $CO_2$ | Carbon Dioxide |
| COLREGS | International Regulations for Preventing Collisions at Sea 1972 |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| cP | Centipascals |
| DAC | Djarindjin Aboriginal Corporation |
| DAWR | Department of Agriculture and Water Resources |
| dB | Decibel |
| DBCA | Department of Biodiversity, Conservation and Attractions |
| DEC | Department of Environment and Conservation |
| DEH | Department of Environment and Heritage |
| DEWHA | Department of Environment, Water, Heritage and the Arts |
| DFES | Department of Fire and Emergency Services |
| DHA | Department of Home Affairs |
| DIIS | Department of Industry, Innovation and Science |
| DMIRS | Department of Mines, Industry Regulation and Safety |
| DMP | Department of Mines and Petroleum |
| DO | Dissolved Oxygen |
| DoE | Department of the Environment |

| | |
|---|---|
| DoEE | Department of the Environment and Energy |
| DoF | Department of Fisheries |
| DP | Dynamic Positioning |
| DPIRD | Department of Primary Industries and Regional Development |
| DPLH | Department of Planning, Lands and Heritage |
| DSEWPaC | Department of Sustainability, Environment, Water, Population and Communities |
| DWER | Department of Water and Environmental Regulation |
| EAA | East Asian-Australasian |
| EHS | Environment Health and Safety |
| EIS | Environmental Impact Statement |
| EPBC Act | *Environmental Protection, Biodiversity and Conservation Act 1999* |
| EPs | Environmental Plans |
| E&P Forum | Exploration and Production Forum |
| EPOs | Environmental Performance Outcomes |
| ESD | Ecologically Sustainable Development |
| ESHIA | Environment, Social, and Health Impact Assessment |
| FEED | Front End Engineering and Design |
| FID | Financial Investment Decision |
| FLNG | Floating Liquefied Natural Gas |
| FPSO | Floating Production Storage and Offloading |
| g | Grams |
| GHG | Greenhouse Gas |
| h | Hour |
| ha | Hectares |
| HEMP | Hazards and Effects Management Process |
| $H_2S$ | Hydrogen Sulfide |
| HSE | Health Safety and Environment |
| HSSE | Health, Security, Safety, the Environment |
| HSSE & SP | Health, Security, Safety, the Environment and Social Performance |
| HSSE & SP-MS | Health, Security, Safety, the Environment and Social Performance Management System |
| HVAC | Heating, Ventilating and Air Conditioning |
| Hz | Hertz |
| IOGP | International Association of Oil and Gas Producers |
| IEA | International Energy Agency |
| IFC | International Finance Corporation |
| IFO | Intermediate Fuel Oil |
| IMS | Invasive Marine Species |
| IMO | International Marine Organisation |
| ISO | International Standards Organisation |
| ISQG | Interim Sediment Quality Guideline |
| IPCC | Intergovernmental Panel on Climate Change |
| IPIECA | International Petroleum Industry Environmental Conservation Association |
| ITF | Indonesian Throughflow |
| IUCN | International Union for Conservation of Nature |
| JAMBA | Agreement Between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and Their Environment 1974 |

| | |
|---|---|
| KBAs | Key Biodiversity Areas |
| KDL | Key Decision Log |
| KEF | Key Ecological Features |
| kHz | kilohertz |
| kJ | Kilojoule |
| km | Kilometers |
| L | Litres |
| $L_{E,p}$ | Sound Exposure Level |
| $L_p$ | Sound Pressure Level |
| $L_{pk}$ | Peak Pressure Level |
| LNG | Liquified Natural Gas |
| LP | Low Pressure |
| LPG | Liquified Petroleum Gas |
| m | Meters |
| mm | Millimeters |
| MARPOL 73/78 | International Convention for the Prevention of Pollution from Ships 1973 |
| MEG | Monoethylene Glycol |
| mg | Milligrams |
| MNES | Matters of National Environmental Significance |
| MoU | Memorandum of Understanding |
| MPPE | Macro-Porous Polymer Extraction |
| mtpa | Million Tonnes Per Annum |
| µPa | Micropascals |
| MPR | Modular Platform Rig |
| NAGD | National Assessment Guidelines for Dredging |
| NAXA | North Australian Exercise Area |
| NEPC | National Environmental Protection Council |
| NEPMS | National Environmental Protection Measures |
| NGER | National Greenhouse and Energy Reporting |
| nm | Nautical Mile |
| NMR | North Marine Region |
| NNM | Not Normally Manned |
| NOAA | National Ocean and Atmospheric Administration |
| NOEC | No Observed Effect Concentration |
| NORM | Naturally Occurring Radioactive Material |
| NOPSEMA | National Offshore Petroleum Safety and Environmental Management Authority |
| NOPTA | National Offshore Petroleum Titles Administrator |
| $NO_X$ | Oxides of Nitrogen |
| NPD | Naphthalene, Phenanthrene, Dibenzothiophene |
| NPI | National Pollutant Inventory |
| NRETAS | Department of Natural Resources, Environment, the Arts and Sport |
| NT | Northern Territory |
| NWMR | North-west Marine Region |
| NWS | North West Shelf |
| NWSTF | North West Slope Trawl Fishery |
| ODS | Ozone Depleting Substance |
| OPEP | Oil Pollution Emergency Plan |
| OPEX | Operational Expenditure |

| | |
|---|---|
| OPGGS | Offshore Petroleum and Greenhouse Gas Storage |
| OPGGS (E) Regulations | Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations, 2009 |
| OPP | Offshore Petroleum Proposal |
| OSMP | Operational and Scientific Monitoring Program |
| PAH | Polycyclic Aromatic Hydrocarbon |
| PAR | Photosynthetically Active Radiation |
| PFW | Produced Formation Water |
| PLET | Pipeline End Termination |
| ppb | Parts Per Billion |
| ppm | Parts Per Million |
| POB | Persons on Board |
| POTS Act | *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* |
| PSU | Practical Salinity Unit |
| PTTEP | Petroleum Authority of Thailand Exploration and Production |
| PTS | Permanent Threshold Shift |
| PQL | Practical Quantification Limit |
| PWSNT | Parks and Wildlife Service Northern Territory |
| RAM | Risk Assessment Matrix |
| Ramsar | International Convention on Wetlands of International Importance |
| ROKAMBA | Agreement Between the Government of Australia and the Government of the Republic for Korea for the Protection of Migratory Birds and Their Environment, 2002 |
| RO | Reverse Osmosis |
| SEL | Sound Exposure Level |
| SBM | Synthetic Based Mud |
| SGG | Synthetic Greenhouse Gas |
| SGH | Seven Group Holdings |
| Shell | Shell Australia Proprietary Limited |
| SIMPOS | Simulataneous Operations |
| SOLAS convention | The International Convention for the Safety of Life at Sea 1974 |
| $SO_x$ | Sulphur Oxides |
| SPL | Sound Pressure Level |
| STCW Convention | International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 |
| TEG | Triethylene Glycol |
| TKN | Total Kjeldahl Nitrogen |
| TLP | Tension Leg Platform |
| tpa | Tonnes Per Annum |
| TPH | Total Petroleum Hydrocarbons |
| TRH | Total Recoverable Hydrocarbons |
| TTS | Temporary Threshold Shift |
| TSS | Total Suspended Solids |
| µm | Micrometre |
| WA | Western Australia |
| WAFIC | Western Australian Fishing Industry Council |
| WAM | Western Australian Museum |
| WAMSI | Western Australian Marine Science Institution |
| WB | World Bank |

| | |
|---|---|
| WBM | Water Based Mud |
| WET | Whole Effluent Toxicity |
| WOB | Water Over Board |
| WOMP | Well Operations Management Plan |
| w/w | Weight per Weight |
| VOCs | Volatile Organic Compounds |
| VSP | Vertical Seismic Profiling |

## 10.3 Disclaimer

This document contains data and analysis from Shell's Sky scenario. Unlike Shell's previously published Mountains and Oceans exploratory scenarios, the Sky scenario is based on the assumption that society reaches the Paris Agreement's goal of holding the rise in global average temperatures this century to well below two degrees Celsius (2°C) above pre-industrial levels. Unlike Shell's Mountains and Oceans scenarios, which unfolded in an open-ended way based upon plausible assumptions and quantifications, the Sky scenario was specifically designed to reach the Paris Agreement's goal in a technically possible manner. These scenarios are a part of an ongoing process used in Shell for over 40 years to challenge executives' perspectives on the future business environment. They are designed to stretch management to consider even events that may only be remotely possible. Scenarios, therefore, are not intended to be predictions of likely future events or outcomes.

Additionally, it is important to note that as of 26 June 2020, Shell's operating plans and budgets do not reflect Shell's net-zero emissions ambition. Shell's aim is that, in the future, its operating plans and budgets will change to reflect this movement towards its new net-zero emissions ambition. However, these plans and budgets need to be in step with the movement towards a net-zero emissions economy within society and among Shell's customers.

Also, in this presentation we may refer to "Shell's Net Carbon Footprint", which includes Shell's carbon emissions from the production of our energy products, our suppliers' carbon emissions in supplying energy for that production and our customers' carbon emissions associated with their use of the energy products we sell. Shell only controls its own emissions but, to support society in achieving the Paris Agreement goals, we aim to help and influence such suppliers and consumers to likewise lower their emissions. The use of the terminology "Shell's Net Carbon Footprint" is for convenience only and not intended to suggest these emissions are those of Shell or its subsidiaries.

The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate legal entities. In this presentation "Shell", "Shell group" and "Royal Dutch Shell" are sometimes used for convenience where references are made to Royal Dutch Shell plc and its subsidiaries in general. Likewise, the words "we", "us" and "our" are also used to refer to Royal Dutch Shell plc and its subsidiaries in general or to those who work for them. These terms are also used where no useful purpose is served by identifying the particular entity or entities. ''Subsidiaries'', "Shell subsidiaries" and "Shell companies" as used in this presentation refer to entities over which Royal Dutch Shell plc either directly or indirectly has control. Entities and unincorporated arrangements over which Shell has joint control are generally referred to as "joint ventures" and "joint operations", respectively. Entities over which Shell has significant influence but neither control nor joint control are referred to as "associates". The term "Shell interest" is used for convenience to indicate the direct and/or indirect ownership interest held by Shell in an entity or unincorporated joint arrangement, after exclusion of all third-party interest.

This presentation contains forward-looking statements (within the meaning of the U.S. Private Securities Litigation Reform Act of 1995) concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as "aim", "ambition', ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''goals'', ''intend'', ''may'', ''objectives'', ''outlook'', ''plan'', ''probably'', ''project'', ''risks'', "schedule", ''seek'', ''should'', ''target'', ''will'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this presentation, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for Shell's products; (c) currency fluctuations; (d) drilling and production results; (e) reserves estimates; (f) loss of market share and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including regulatory measures addressing climate change; (k) economic and financial market conditions in various countries and regions; (l) political risks, including the risks of expropriation and renegotiation of the terms of contracts with governmental entities, delays or advancements in the approval of projects and delays in the reimbursement for shared costs; (m) risks associated with the impact of pandemics, such as the COVID-19 (coronavirus) outbreak; and (n) changes in trading conditions. No assurance is provided that future dividend payments will match or exceed previous dividend payments. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Additional risk factors that may affect future results are contained in Royal Dutch Shell's Form 20-F for the year ended December 31, 2019 (available at www.shell.com/investor and www.sec.gov ). These risk factors also expressly qualify all forward-looking statements contained in this presentation and should be considered by the reader. Each forward-looking statement speaks only as of the date of this document, 26 June 2020. Neither Royal Dutch Shell plc nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

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