How to Make a Submission

The Western Australian Environmental Protection Authority (EPA) invites people to make a submission on this proposal. The environmental impact assessment process is designed to be transparent and accountable, and includes specific points for public involvement, including opportunities for public review of the Strategic Assessment documents. In releasing this document for public comment, the EPA advises that no decisions have been made to allow this proposal to be implemented.

The State of Western Australia, through the Minister for State Development (the Proponent), proposes to develop an onshore, common-user Liquefied Natural Gas (LNG) Precinct to process natural gas from Browse Basin gas fields off the west Kimberley coast. The Department of State Development (DSD) has been charged with advancing this proposal under the direction of the Proponent.

In accordance with the *Environmental Protection Act 1986* and the *Environment Protection and Biodiversity Conservation Act 1999*, a **Strategic Assessment Report** (**SAR**) has been prepared which describes this proposal and its likely effects on the environment. The Strategic Assessment Report is presented in seven parts. The first six parts of the SAR were released for public review on 13 December 2010, with the proviso that Supplementary Information which addresses Marine Wastewater Discharge Modelling, Hydrocarbon Spill Modelling, Marine Benthic Primary Producer Habitat Calculations, and Coastal Processes Modelling would be available for public review in early 2011 for a minimum of 6 weeks. Public Review of the Supplementary Information commences 14 February 2011.

The Strategic Assessment Report and Supplementary Information (all seven parts) can be downloaded from the EPA consultation portal at http://public-consult.epa.wa.gov.au/portal

Public submissions on both the Strategic Assessment Report and Supplementary Information (all seven parts) will now close on 28 March 2011.

Where to get copies of this document

The document/s may be accessed through the consultation portal at http://public-consult.epa.wa.gov.au/portal or the proponent's website at http://www.dsd.wa.gov.au/. This online public consultation portal will provide a user friendly platform to review the documentation and submit comments directly to the EPA.

Printed copies of the Executive Summary with a CD of the full document and Appendices may also be obtained from Sarah Woods, Department of State Development, Level 6, 1 Adelaide Terrace, East Perth, Western Australia 6004 (telephone: 9222 3191) free of charge. A limited number of the full set of documents have also been printed for distribution to key agencies, stakeholder groups and for placement in libraries.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Electronic submissions will be acknowledged electronically. The proponent will be required to provide adequate responses to points raised in submissions. In preparing its assessment report for the Minister for the Environment, the EPA will consider the information in submissions, the proponent's responses and other relevant information. Submissions will be treated as public documents unless provided and received in confidence, subject to the requirements of the *Freedom of Information Act 1992*, and may be quoted in full or in part in each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the **SAR** or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the **SAR**:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable; and
- suggest recommendations, safeguards or alternatives.

Points to keep in mind.

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the **SAR**;
- if you discuss different sections of the **SAR**, keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name,
- address,
- date; and
- whether you want your submission to be confidential.

The closing date for submissions on both the Strategic Assessment Report and Supplementary Information (all seven parts) is: **28 March 2011.**

The EPA prefers submissions to be made via the consultation portal at:

http://public-consult.epa.wa.gov.au/portal

Alternatively, submissions can be:

- made by email to submissions@epa.wa.gov.au;
- posted to: Chairman, Environmental Protection Authority, Locked Bag 33, CLOISTERS SQUARE WA 6850, Attention: Warren Tacey; or
- delivered to the Environmental Protection Authority, Level 4, The Atrium, 168 St Georges Terrace, Perth, Attention: Warren Tacey.

If you have any questions on how to make a submission, please ring the EPA assessment officer, Warren Tacey on 6467 5710 or Kathryn Schell on 6467 5426.

Browse LNG Precinct

Strategic Assessment Report – Structure Display

The State of Western Australia, through the Minister for State Development, has developed the Browse LNG Precinct Strategic Assessment Report (SAR) to enable consideration of a proposed common user liquefied natural gas (LNG) Precinct to process natural gas from the Browse Basin gas fields, at a location near James Price Point, approximately 60 kilometres north of Broome. This SAR is presented in seven parts as shown in the following diagram. You are invited to make a submission by visiting the Environmental Protection Authority website at http://public-consult.epa.wa.gov.au/portal. Appendices are also available at http://www.dsd.wa.gov.au/browseLNG.

APPENDIX D

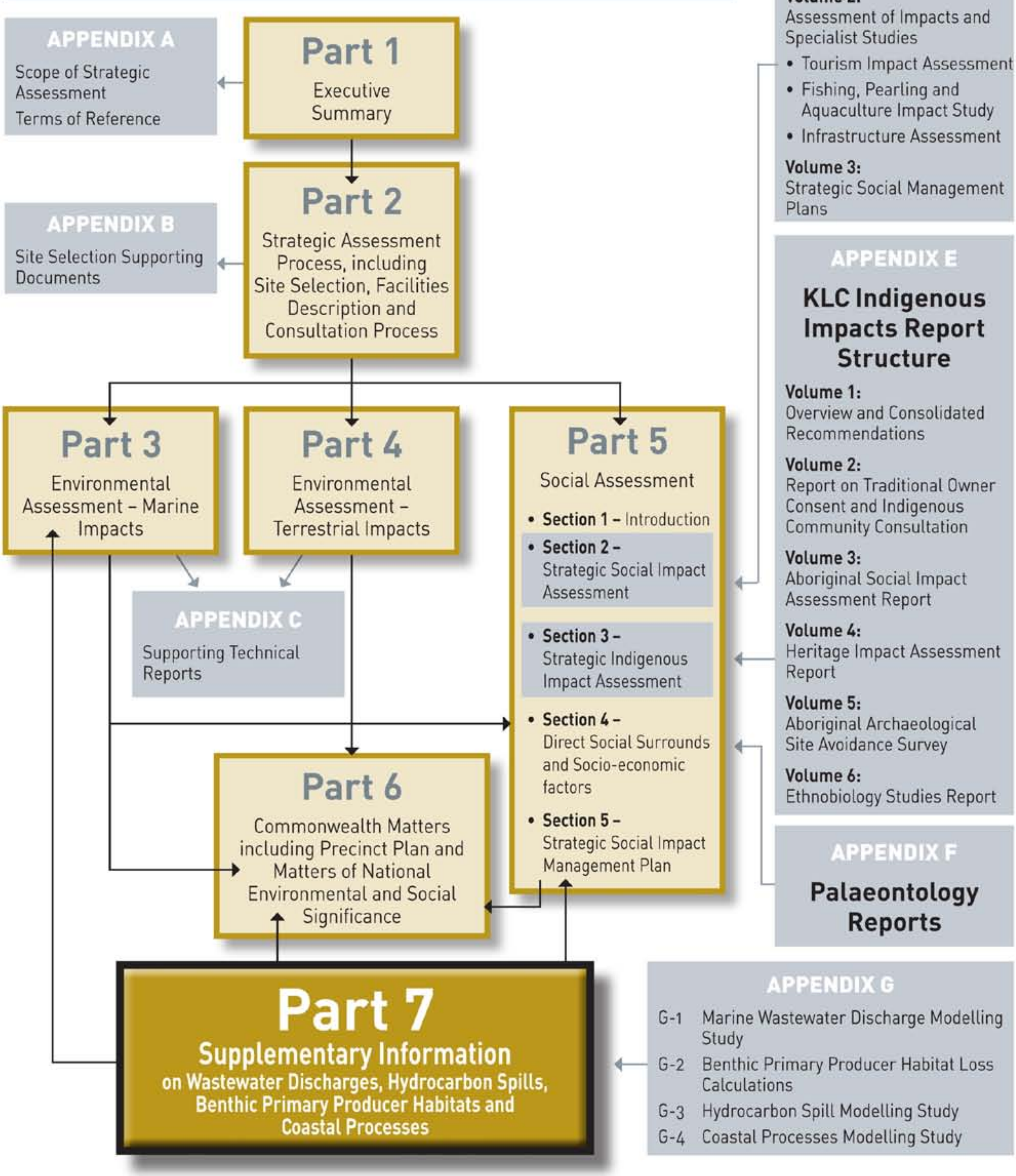
DSD Strategic SIA Structure

Volume 1:
Scope and Profile

Volume 2:
Assessment of Impacts and Specialist Studies

- Tourism Impact Assessment
- Fishing, Pearling and Aquaculture Impact Study
- Infrastructure Assessment

Volume 3:
Strategic Social Management Plans



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1. Introduction

1.1. Background to the BLNG Strategic Assessment

The State of Western Australia (**WA**), through the Minister for State Development (the **Proponent**), proposes to develop an onshore, common-user Liquefied Natural Gas (**LNG**) precinct to process natural gas from Browse Basin gas fields off the west Kimberley coast. The Department of State Development (**DSD**) has been charged with advancing this proposal under direction of the Proponent.

The Browse Liquefied Natural Gas Precinct (**BLNG Precinct** or **Precinct**) would consist of LNG processing facilities and associated infrastructure, and would be located in the vicinity of James Price Point, approximately 60 kilometres (**km**) north of Broome, on the west Kimberley coast of Western Australia. The BLNG Precinct would provide a location for processing gas and associated products from the Browse Basin with an LNG production capacity of up to 50 million tonnes per annum (**Mtpa**). If it were to occur, full development of the Precinct would most likely be phased in as demand for additional processing capacity arises. The Precinct would accommodate a minimum of two **proponents** at one location and enable sharing of common-user facilities such as the port, roads, infrastructure corridors and workers' accommodation. A **Precinct Plan** has been developed to meet the requirements of the State and Commonwealth Governments.

Woodside Energy Limited (**Woodside**), on behalf of the Browse LNG Development Joint Venture participants, was appointed as a potential Foundation Proponent for the Precinct under the Preliminary Development Agreement signed in October 2009. This Agreement established Woodside as a partner with the State Government in bringing the project to completion.

A detailed and comprehensive assessment has considered the environmental, social, economic, heritage and strategic implications of the Precinct should it reach its full capacity. The assessment process has involved desktop studies, field surveys, modelling, data analysis, impact assessment and stakeholder consultation, the results of which are documented in the BLNG Precinct Strategic Assessment Report (**SAR**).

The purpose of the Strategic Assessment Report is to meet the requirements of the State and Commonwealth governments in accordance with the Terms of Reference. The Strategic Assessment includes a high level impact assessment (including social factors), a description of the strategic proposal, identifying 'future proposals' (to be approved under the *Environmental Protection Act 1986* (the **EP Act**)) and the Precinct Plan (to be endorsed under the *Environment Protection and Biodiversity Conservation Act 1999* (the **EPBC Act**)), and includes the Proponent's proposed draft conditions that may be applied to future proposals. The document includes a summary of existing information, identifying main impact areas and sets out the proposed management arrangements, mitigation and safeguards to ensure impacts are managed.

The Strategic Assessment Report is presented in seven parts:

Part 1: Executive Summary

Part 2: Strategic Assessment Process including Site Selection, Facilities Description and Consultation Process

Part 3: Environmental Assessment – Marine Impacts

Part 4: Environmental Assessment – Terrestrial Impacts

Part 5: Social Assessment

Part 6: Commonwealth Matters including Precinct Plan, Management Arrangements and Matters of National Environmental and Social Significance

Part 7: Supplementary Information on Wastewater Discharges, Benthic Primary Producer Habitats (**BPPH**), Hydrocarbon Spills and Coastal Processes.

This document (**Part 7**) provides a summary of four supplementary technical studies with the complete reports provided as technical appendices, included in the accompanying CD.

The first six parts of the Strategic Assessment Report were released for public review on 13 December 2010, with the proviso that supplementary information (**Part 7**) would be available for public review in early 2011 for a minimum of six weeks. All seven parts are now available for download from the consultation portal at http://public-consult.epa.wa.gov.au/portal or DSD's website at http://www.dsd.wa.gov.au/BrowseLNG. Public submissions on the SAR (all seven parts) will close on 28 March 2011.

1.2. SAR Part 7: Supplementary Information

This document (**Part 7**) provides a summary of four supplementary technical studies:

1) Marine Wastewater Discharge Modelling (DHI, 2011a; **Appendix G-1**);
2) Marine Benthic Primary Producer Habitat Calculations (SKM, 2011; **Appendix G-2**);
3) Hydrocarbon Spill Modelling (DHI 2011b; **Appendix G-3**); and
4) Coastal Processes Modelling (DHI, 2011c; **Appendix G-4**).

The intent of this document is to:

- **Summarise the objectives, methodology and results** of the four technical studies undertaken to inform the strategic assessment. Summary results are presented in this document, with the complete reports provided as technical appendices, included in the accompanying CD.
- **Describe the results** of the technical studies in the context of the impact conclusions and outcomes published elsewhere in the SAR.
- **Review the outcomes** of the supplementary technical studies to determine whether the predicted impacts, and corresponding management measures, are acceptable and manageable in the context of the BLNG Strategic Assessment.

As part of this process, independent peer reviewers were engaged to review the methodology, outcomes and conclusions of the three modelling studies (marine discharge modelling, hydrocarbon spill modelling and coastal processes modelling). The information presented in this document has been reviewed and endorsed by the peer reviewers as being technically robust using appropriate methods and assumptions.

Overall, the assessment of the impacts on the environment, as confirmed by this supplementary information, demonstrates that the site selection process undertaken by the Northern Development Taskforce (**NDT**) succeeded in ensuring that most areas of environmental significance or sensitivity were avoided. It also supports the S16(e) advice of the Environmental Protection Authority (**EPA**) that environmental risks and impacts were likely to be manageable (EPA, 2008).

2. Marine Wastewater Discharge Modelling

2.1. Introduction

Wastewater treatment facilities would be developed to treat and manage wastewater generated from the LNG facilities and supporting utilities and associated infrastructure. Potential wastewater streams that would require treatment prior to discharge to an approved location are described in **Part 2**, **Section 5** (Description of Activities and Facilities), and include:

- produced water and associated liquid effluent from LNG processing;
- condensed wastewater from associated infrastructure;
- contaminated water from process areas;
- surface runoff (for example stormwater) from process areas;
- sanitary wastewater (sewage and grey water); and
- other wastewater associated with provision and supply of water (such as brine water) for the LNG facilities at the Precinct.

Treatment methodologies have yet to be selected and are highly dependent upon the characteristics of the wastewater stream. Once treated, wastewater would be disposed of according to water quality criteria to meet environmental protection guidelines. It is likely to be discharged via marine outfalls located offshore within the Port development area, with exact locations to be defined as part of the detailed engineering design work by project proponents, and would be considered by the EPA at the derived proposal stage. Impact assessment conclusions related to marine discharges are provided in **Part 3** (Environmental Assessment – Marine Impacts), and social factors are considered in **Part 5** (Social Assessment). The following section provides a summary of the results of wastewater discharge modelling undertaken to inform the strategic assessment, specifically to determine whether the predicted impacts, and corresponding management measures, are acceptable and manageable in the context of the BLNG Strategic Assessment.

2.2. Relevant Factors

2.2.1. Environmental Factors

The study conclusions for marine discharge modelling are primarily relevant to the following environmental factors:

- Marine Sediments (**Part 3**, **Section 2.2**);
- Marine Water Quality (**Part 3**, **Section 2.3**);
- Benthos including Benthic Primary Producers (**BPP**) (**Part 3**, **Section 2.4**); and
- Marine Ecosystem Integrity (**Part 3**, **Section 2.8**).

2.2.2. Social Factors

The study conclusions for marine discharge modelling are primarily relevant to the following social factors:

- Commercial Fishing (**Part 5**, **Section 4.5**);
- Aquaculture and Pearling (**Part 5**, **Section 4.6**); and
- Sports, Recreation (including recreational fishing) and Land Use (**Part 5**, **Section 4.8**).

Other factors of less potential significance have been identified, and are addressed in consideration of the primary factors above. These other factors are:

- Species of Ethno-biological Significance (**Part 4**, **Section 2.5**);
- Customary Fishing (**Part 5**, **Section 3.8**); and
- Potential Socio-economic Impacts on Indigenous People (**Part 5**, **Section 3.4**).

The results of these studies are contained in **Part 5** and are consistent with the findings of this modelling study. For completeness, **Section 2.4.1.2** includes a summary of these relevant social factors and the impact conclusions.

2.3. Study Overview

2.3.1. Objectives

The study was undertaken to meet the following key overall objectives:

- To present the modelling process undertaken for wastewater discharges under various discharge scenarios at 25Mtpa and 50Mtpa LNG production.
- To determine the near-field active mixing zone and far-field mixing zone footprints (size and scale) and dilution levels for mixing zones during a spring-neap[1] cycle for both winter and summer. The modelling also included investigation of the sensitivity to the following:
    - location of outfall (i.e. depth and distance from shore, and comparison of northern versus southern locations);
    - wastewater discharge type; and
    - flow rate of the wastewater stream.

It may be noted that characterisation of the extent of the mixing zone is of key importance because trigger values at a selected species protection level, as defined under the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (**ANZECC/ARMCANZ**, 2000) Australian and New Zealand national water quality guidelines, will be determined at the boundary of the active mixing zone.

2.3.2. Methodology Overview

A dispersion modelling study was undertaken by DHI Water and Environment Pty Ltd (**DHI**) (DHI, 2011a; **Appendix G-1**) to simulate the discharge of process water and potential brine water streams in order to inform the Strategic Assessment. To examine the potential range of environmental outcomes in terms of the size of mixing zones and dilution levels, different scenarios were assessed under summer and winter conditions with different discharge rates. A summary overview of the approach is presented below, with further details included in **Appendix G-1**.

A near-field discharge model (CORMIX model) was used to assess the dilution of the plume at the active mixing zone under a range of ambient summer and winter conditions. The results of the near-field modelling are important as these will assist in determining the size of the active mixing zone boundary where the ANZECC/ARMCANZ 2000 water quality guidelines will be applied.

A validated fine-mesh coastal hydrodynamic model (**MIKE21 HD**) was used to generate two-dimensional current data for the study region. An Advection Dispersion model (**MIKE21 AD**) was then used to estimate the extent and shape of mixing zones in the far-field. The dilution levels at the end of the active mixing zone have been integrated into the far-field model outputs. The far-field modelling will assist in determining how active the natural mixing characteristics are at the proposed Precinct location and therefore how much additional mixing will occur after the ANZECC /ARMCANZ 2000 water quality guidelines have been met. As the primary purpose of the far-field modelling is to determine the amount of natural mixing post meeting the guidelines (and therefore assess the 'natural' mixing characteristic) the port infrastructure was excluded from the model. **Figure 2-1** summarises the modelling approach which is outlined further in **Appendix G-1**.

Not including a port layout ensured that the extent of the dilution field was determined by ambient flow conditions. The inclusion of port structures would generally be expected to increase the extent of mixing due to increased turbulence generated by the structures and increased velocities as water flows around these structures which would result in greater mixing (and therefore increase dilution effects). This in some cases may be countered by the 'shadowing' effect of breakwaters reducing current speeds (See Figure 6.7 in **Appendix G-4**). However this mixing is not relied upon to meet the ANZECC /ARMCANZ 2000 water quality guidelines, but shows the indicative level of additional mixing that may occur outside the active mixing zone.

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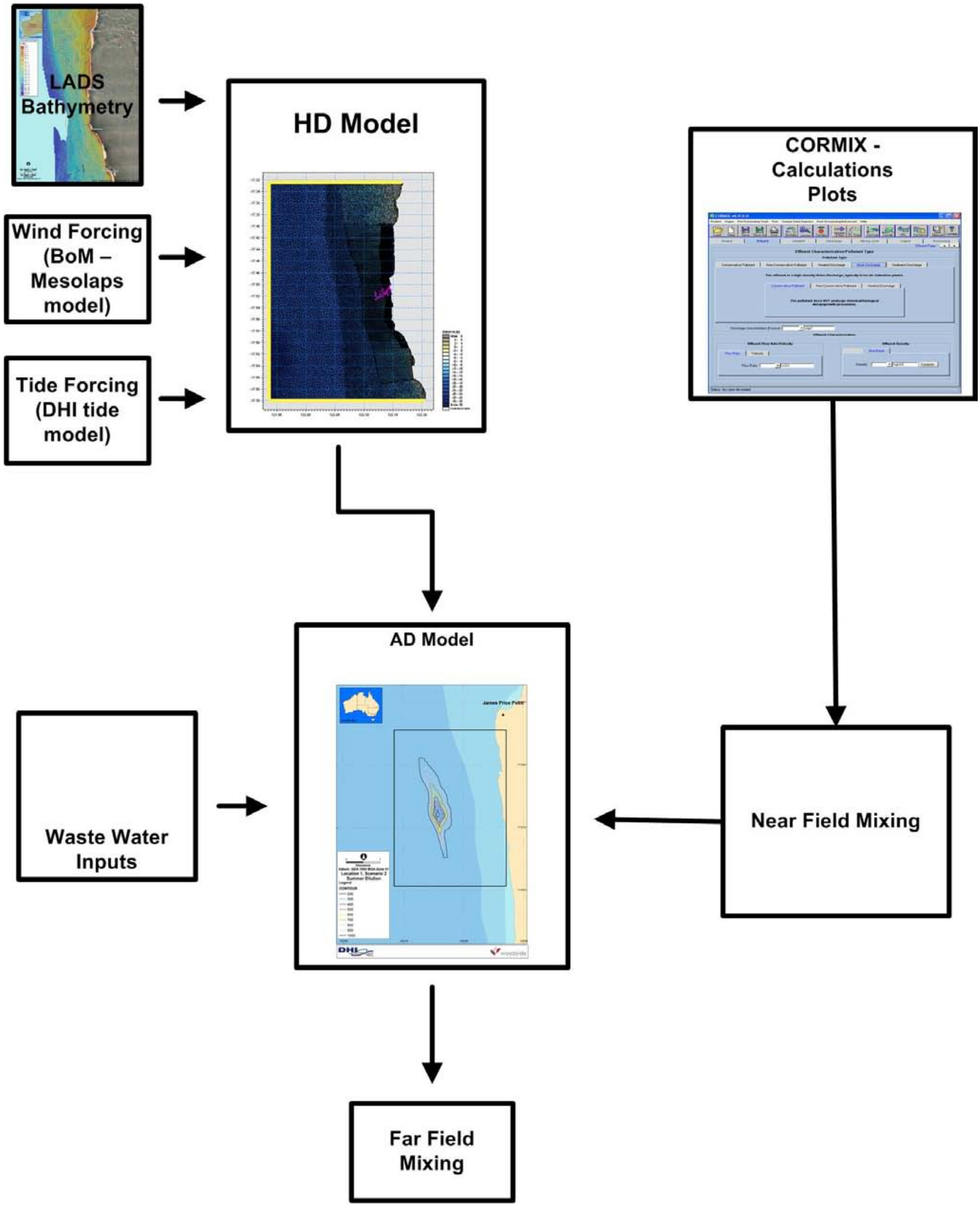
[1] Spring tides are tides of increased range occurring semi-monthly as the result of a new or full moon, and typically result in maximum tidal movement. Neap tides are tides of decreased range or tidal currents of decreased speed occurring semi-monthly when the moon is at first quarter or third quarter, and typically result in minimum tidal movement.

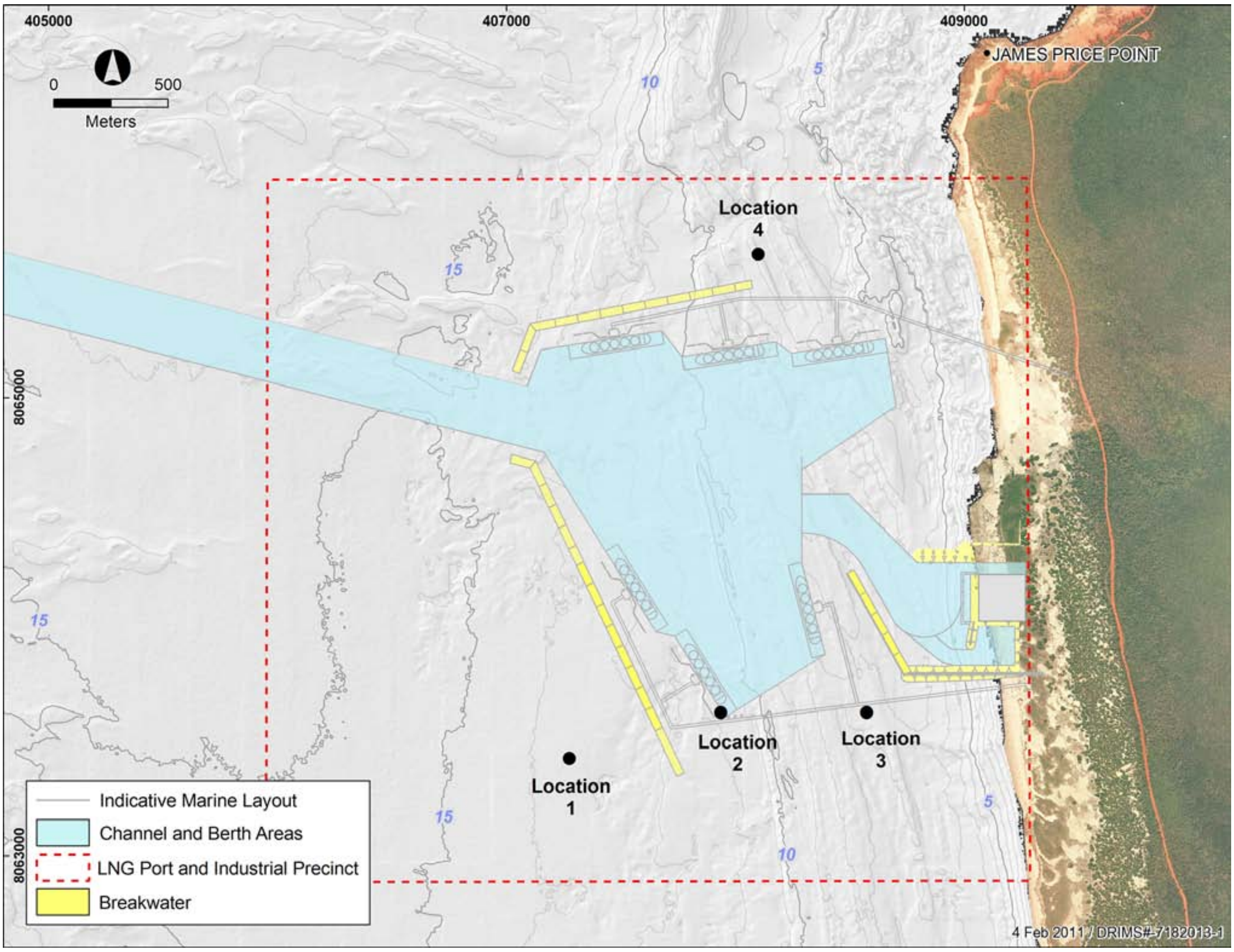


- **Figure 2-1 Conceptual Diagram of Modelling Approach for Wastewater Discharges.**

In order to inform this modelling study, four notional discharge locations were selected in order to allow assessment of any differences in plume dispersion (**Figure 2-2**), to test sensitivity of results to changes in outfall location and depth.

Further details on model setup, data inputs and validation are presented in **Appendix G-1** (Sections 5 and 6) and supporting technical appendices.

For the purposes of a strategic level assessment, it was assumed that the outfall(s) would be equipped with a multiport diffuser to increase initial mixing and dilution of discharged wastewater in the receiving waters. Sensitivity tests were undertaken of possible diffuser designs to ensure conservative (worst case) modelling assumptions were adopted.



- **Figure 2-2 Assumed Notional Outfall Locations.**

2.3.3. Key Findings

The results of the near-field model provide predictions of dilution levels and footprints of the active mixing zone. Depending on the scenario, the active mixing zone would remain within 300 metres (**m**) of the discharge location. Modelling indicates a range in length between 40-300m from the point of discharge, with an upper extent of 200-300m.

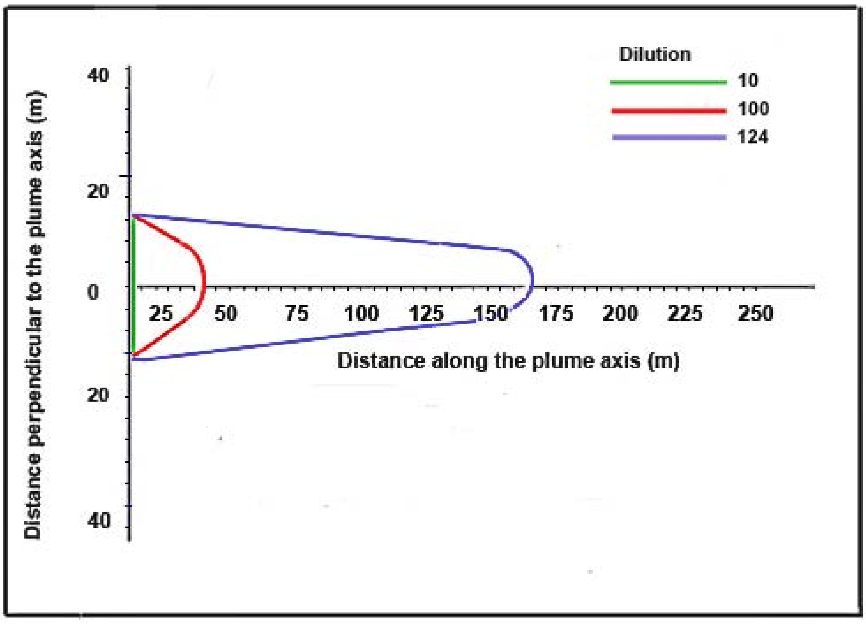
Overall, key conclusions based on near-field model simulations are that:

- For process wastewater discharges, an increase in discharge rate decreases the dilution rate at the edge of the near-field mixing zone and increases the footprint of the near-field mixing zone.
- For brine water discharges, an increase in discharge rate causes a decrease in dilution rate at the edge of the near-field mixing zone and increases the footprint of the near-field mixing zone.
- An increase in ambient current speed significantly increases the dilution rate at the edge of the near-field mixing zone and decreases the footprint of the near-field mixing zone.
- The distance to achieve a 1:10 dilution level is less than 1m in most cases.
- The distance to achieve a 1:100 dilution level is less than 10m during strong currents and less than 30m during weak currents.

It should be noted that the final diffuser design, location and discharge rate will change the size of the active mixing zone. However the modelling scenarios show that the active mixing zone would remain within 300m of the discharge location.

From a strategic perspective the conclusions from the near-field modelling is that dilutions in excess of 100 times should readily be achievable within a 300m (maximum) size active mixing zone. The final design of the outfall(s) and resulting dilution calculations will need to account for other port structures to determine the actual dilution level achievable. This ‘actual’ dilution will then be multiplied by the concentration in the ANZECC/ARMCANZ 2000 water quality guidelines to get the discharge water quality parameters. Consequently the combination of design of the water treatment system and diffuser will need to meet the ANZECC/ARMCANZ 2000 water quality guidelines at the edge of the active mixing zone. Any increase or reduction in the achievable number of dilutions as a result of interference from other structures or sub-optimal diffuser design will require corresponding changes in the treatment of the discharge to meet the guidelines.

A representative figure showing the typical results of near-field modelling is presented as **Figure 2-3**. Full detailed plots are provided in **Appendix G-1**.



- **Figure 2-3 Representative Modelling Output of Near-field Dilutions for Process Wastewater (7.5m depth, Scenario 2, representing 550m^3/hr, freshwater – Figure 7.2 in Technical Report).**

Note: Refer **Appendix G-1** for all Contour Plots.

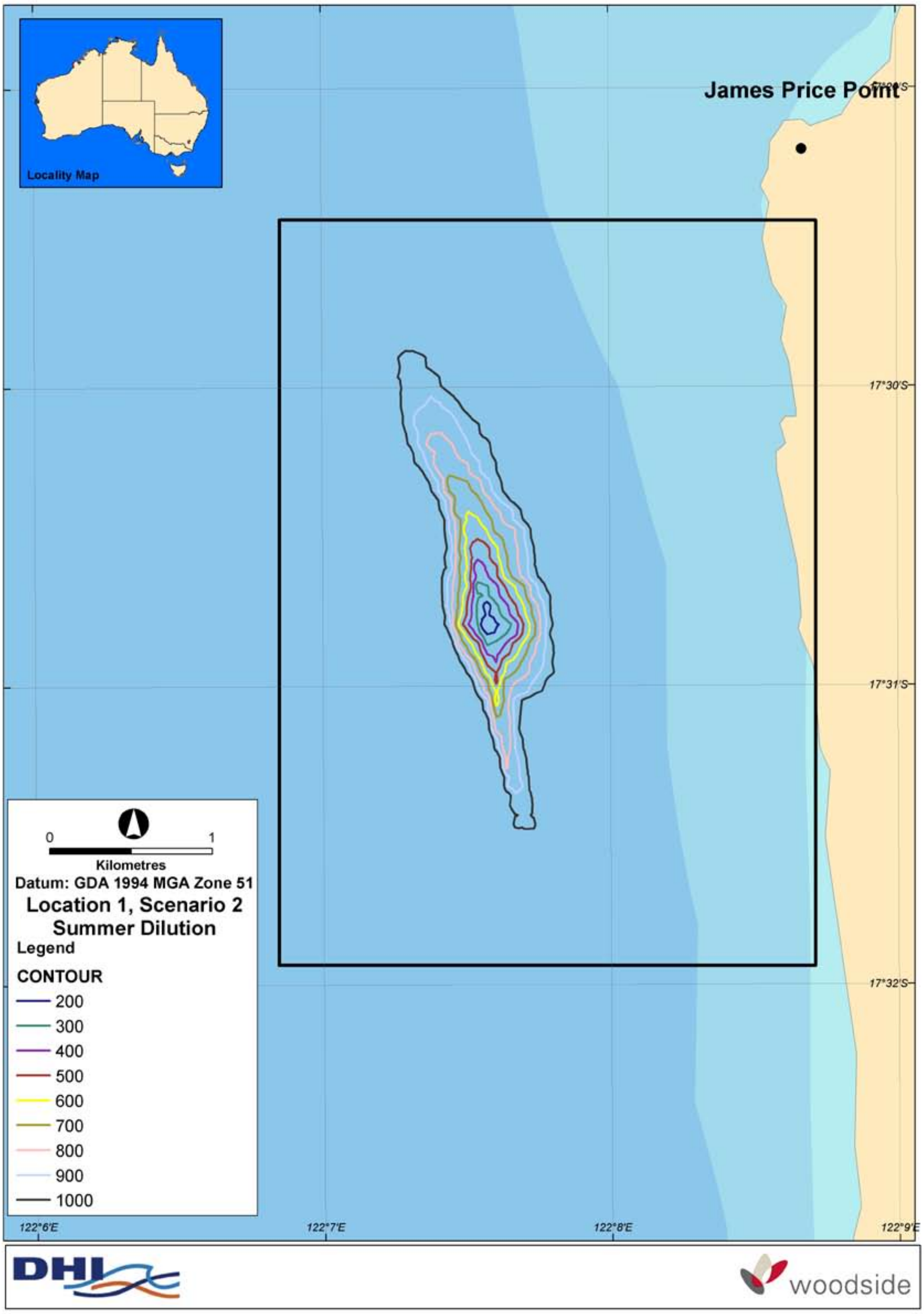
The results of the far-field model provide predictions of the extent and shape of mixing, and quantify the additional dilution levels at the boundary of the far-field mixing zone. A representative figure showing the typical results of modelling is presented as **Figure 2-4**, showing the maximum extent of discharge zones to be contained within the BLNG Precinct port area. Full detailed plots are provided in **Appendix G-1**. Each contour on **Figure 2-4** represents the predicted dilution factor relative to the original concentration of the wastewater stream at the point of discharge.

The far-field model results indicate that the plume would spread in a north-south direction due to the oscillating tidal flow. The wastewater plume appears to disperse rapidly in this well-mixed environment.

The key conclusions based on far-field model simulations are that:

- The dominant factor influencing the spread of the wastewater plume is the advection by the tidal current.
- The winds play a secondary role in the advection of the wastewater plume.
- The dilution rate is found to be sensitive to the discharge rate and depth of discharge.
- The model indicates that seasonal variability would not play a significant role in the advection of the plume, proving the assertion that tidal circulation is the dominant forcing mechanism.
- The size and orientation of dilution contours are similar for summer and winter seasons and dilution rates are comparable in most cases.
- Significant dilution of discharges would continue to occur outside of the active mixing zone due to the tidal currents. Dilutions of 300 to greater than 1,000 can be expected to be achieved within a few kilometres of the outfall.

From a strategic-level assessment perspective, the study findings indicate that wastewater discharges are subject to rapid dilution and dispersion in the receiving waters of the James Price Point coastal area which would provide significant additional dilutions outside the active mixing zone, improving water quality to considerably better than the ANZECC/ARMCANZ 2000 95% species protection level water quality guidelines. With a continual discharge of wastewater at a constant rate, unacceptable low dilution levels are never reached in the James Price Point coastal area due to the ambient strong flows and tidal mixing. Strong flows across an outfall diffuser give rise to high dilution rates. For these reasons, the discharge of process water and brine water, if required, is expected to be readily manageable through the adoption of appropriate treatment technologies, where required, and engineering design of outfalls.



- **Figure 2-4 Representative Modelling Output of Far-field Dilutions for Process Wastewater (Maximum Predicted Summer Extent, Location 1, Scenario 2 (550m^3/hr, freshwater) – Figure 8.2 in Technical Report).**

Note: Black outline represents nominal limit of Port development area. Each contour represents the predicted dilution factor relative to the original concentration of the wastewater stream at the point of discharge. Refer **Appendix G-1** for all Contour Plots.

To ensure a conservative result of the dilution within the active mixing zone, the port layout was excluded from the model setup (see **Section 2.3.2** for further details).

2.4. Assessment against SAR Impact Conclusions and Outcomes

2.4.1. Predicted Impacts

2.4.1.1. Environmental Factors

As stated within **Part 3**, **Section 2.3.4** (Marine Water Quality), the primary impact associated with routine wastewater discharges during construction and operations is the potential to produce a localised zone (i.e. Low Ecological Protection Area 'mixing zone') of reduced water quality within the BLNG Precinct port area.

The wastewater discharge modelling undertaken as part of this SAR Supplementary Information has substantiated the initial impact assessment conclusions within the Strategic Assessment Report. The results demonstrate that, given the dynamic nature of the receiving environment at James Price Point, routine wastewater discharges would be rapidly mixed through the water column such that any contaminants entering receiving waters or deviations in water quality above background would not be detectable, except within the immediate mixing zone (<300m from the discharge point). Therefore, it is predicted that wastewater would meet a 95% level of species protection outside the BLNG Precinct port area according to the definitions of the ANZECC/ARMCANZ 2000 guidelines.

2.4.1.2. Social Factors

Commercial fishing (**Part 5**, **Section 4.5**) is an important industry in the Broome/Dampier Peninsula region and includes managed commercial fisheries (including mackerel, demersal scale fish, prawns, beche de mer and gillnet operations) as well as specimen shell and marine aquarium fish collectors. There are also multiple pearl farm leases in the area with the closest owned by Clipper Holdings Pty Ltd (Clipper Pearls) which is approximately 4-5km west of James Price Point. In the vicinity of James Price Point, both marine and on-shore recreational fishing are popular pastimes. The area is also used for customary fishing (**Part 5**, **Section 3.8**) which significantly supplements the diet of Aboriginal people on the Dampier Peninsula.

The marine wastewater discharge plume would be largely contained in the confines of the port area. The discharge of wastewater would result in localised reduction in water quality in the vicinity of the outfall within the port area. Use of the port area will be restricted with recreational and commercial fishing use not permitted within the port confines (see **Part 5**, **Section 3.8** and **Section 4.8**). However, in accordance with the conclusions of the customary fishing study, the Precinct infrastructure (including the wastewater discharges within) will restrict rather than discontinue customary fishing. Customary and recreational fishing can continue to be practised outside of the Precinct port area.

It is proposed that, through the adoption of appropriate water quality discharge criteria in order to meet ANZECC/ARMCANZ water quality guidelines outside agreed mixing zones within the port, this will achieve mutual social objectives for maintaining water quality standards for aesthetic, recreational, human health, traditional and other values in the area. This is consistent with the proposed scope of a Marine Wastewater Discharge Management Plan, to be developed by future proponents to the satisfaction of the Minister for Environment, as outlined in **Part 3**, **Section 2.3** (Marine Water Quality) and corresponding sections of **Part 5**.

In summary, the social outcomes based on the supplementary wastewater discharge modelling are consistent with those originally presented within **Part 5**.

2.4.2. Mitigation and Management

The environmental outcomes determined from the wastewater discharge modelling study are consistent with those originally presented within the Strategic Assessment Report. The measures outlined primarily within **Part 3**, **Section 2.3.4** (Marine Water Quality) and repeated for the relevant environmental factors **Part 3**, **Section 2.2** (Marine Sediments), **Part 3**, **Section 2.4** (Benthos) and **Part 3**, **Section 2.8** (Marine Ecosystem Integrity) of the Strategic Assessment Report are considered appropriate in mitigating and managing the predicted impacts to achieve an acceptable environmental outcome.

From a social perspective, the wastewater discharge modelling in this section predicts that the plume from the wastewater discharge would be rapidly diluted as a result of the strong tidal movements in the area. The active discharge location would remain within 300m of the discharge location. This falls within the marine exclusion zone of the proposed Precinct and is unlikely to additionally affect fishing (commercial and recreational), aquaculture and recreational uses of the area. The social outcomes determined from the wastewater discharge modelling study are consistent with those originally presented within the Strategic Assessment Report. The key mitigation and management measures, as summarised in the SAR, remain relevant and appropriate to achieve social outcomes.

2.5. Conclusion

The following key conclusions are drawn, taking into account the results of the wastewater discharge study to inform the Strategic Assessment:

- The area is characterised by a highly dynamic nearshore coastal environment driven by semi-diurnal tides. Therefore it experiences regular active flushing to promote rapid dispersion and dilution of discharge streams.
- The extent of the active mixing zone, even at the upper end of capacity for a 50Mtpa Precinct, is expected to be no more than 300m from the discharge points.
- Routine wastewater streams anticipated from the BLNG Precinct would be readily manageable through engineering design and plant operation to meet agreed quality criteria at the boundary of defined mixing zones as committed in the SAR.

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3. Benthic Primary Producer Habitat Calculations

3.1. Introduction

The Environment Assessment Guideline No. 3 (**EAG3**) *(Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment*) outlines a process whereby areas Local Assessment Units (**LAUs**) are defined and used to calculate cumulative losses of Benthic Primary Producer Habitat during the impact assessment process (EPA, 2009). The intent of an LAU is to capture the spatial extent of key functional ecological processes (e.g. circulation patterns, population connectivity, trophic interactions etc.). The guidance encourages proponents to consider aspects of the local marine environment such as bathymetry, position of offshore reefs/islands, substrate type, water circulation patterns, exposure to waves/currents and biological attributes such as habitat types when defining the size and configuration of an LAU.

The following section provides a summary of the results of a technical study undertaken in accordance with the EPA's Environmental Assessment Guideline No. 3 to estimate the historical extent and potential cumulative loss of BPPH. As introductory context, BPPHs are functional ecological communities that inhabit the seabed within which algae, seagrass, mangroves, corals or mixtures of these groups are prominent components. Benthic Primary Producer Habitats also include areas of seabed that can support these communities (EPA, 2009).

3.2. Relevant Factors

3.2.1. Environmental Factors

The study conclusions for the BPPH assessment are primarily relevant to the following environmental factors in the SAR:

- Benthos, including Benthic Primary Producers (**Part 3**, **Section 2.4**); and
- Marine Ecosystem Integrity (**Part 3**, **Section 2.8**).

3.2.2. Social Factors

Although it is not the intended purpose of the study scope to address social factors in the context of local area management units for BPPH, this summary of potential impacts in the context of loss of BPPH is provided for contextual purposes. Further details on the impacts of loss of BPPH on social factors are contained in **Part 5** and are consistent with the findings of this study.

BPPH has a role in the following social factors:

- Commercial Fishing (**Part 5**, **Section 4.5**) – provision of nursery and foraging grounds for commercial species;
- Aquaculture and Pearling (**Part 5**, **Section 4.6**) – provision of food and maintenance of water quality;
- Sports, Recreation (including recreational fishing) and Land Use (**Part 5**, **Section 4.8**) - provision of nursery and foraging grounds for recreational species;
- Species of Ethno-biological Significance (**Part 4**, **Section 2.5**);
- Customary Fishing (**Part 5**, **Section 3.8**); and
- Potential Socio-Economic Impacts on Indigenous People (**Part 5**, **Section 3.4**).

3.3. Study Overview

It is important to note that the EAG3 is intended to provide guidance only and the levels of cumulative loss stipulated are not legislated acceptability criteria. The acceptability of any permanent loss of BPPH will remain the judgement of the EPA, based primarily on the overall risk to ecological integrity within the local assessment unit and noting the comprehensive site selection process that has minimised impacts on regionally important benthic habitats. This section provides a summary overview of the outcomes of BPPH calculations undertaken by Sinclair Knight Merz (**SKM**) to inform the Supplementary Information (SKM, 2011; **Appendix G-2**). These calculations build on the benthic mapping and modelling undertaken to inform **Part 3**, **Section 2.4** (Benthos including Benthic Primary Producers). The modelling uses towed video field survey data, detailed bathymetry and other key environmental parameters to predict the occurrence and abundance of primary BPP types in the area (see **Section 3.3.4.4** for more details).

3.3.1. Objectives

The study was undertaken to meet the following key overall objectives:

- to define an ecologically appropriate LAU relevant to the James Price Point coastal area; and
- to present the results of calculations of cumulative loss of BPPH within the proposed BLNG marine infrastructure in the Port relative to the LAU, in accordance with EAG3.

3.3.2. Methodology – Defining a Local Assessment Unit

The EPA through EAG3 has termed the areas within which to calculate cumulative losses of BPPH as Local Assessment Units (LAUs). The intent of an LAU is to capture the spatial extent of key functional ecological processes (e.g. circulation patterns, larval distribution etc.) and take into account administrative boundaries (i.e. State coastal waters). Consistent with EAG3, the definition of an appropriate LAU for the Browse LNG Development required an assessment of the ecosystem attributes within the James Price Point coastal area and the broader Canning Bioregion. The following sections outline the rationale and justification for an LAU based on ecosystem functionality for the Browse LNG development, and document the predicted benthic habitat loss calculations based on this LAU.

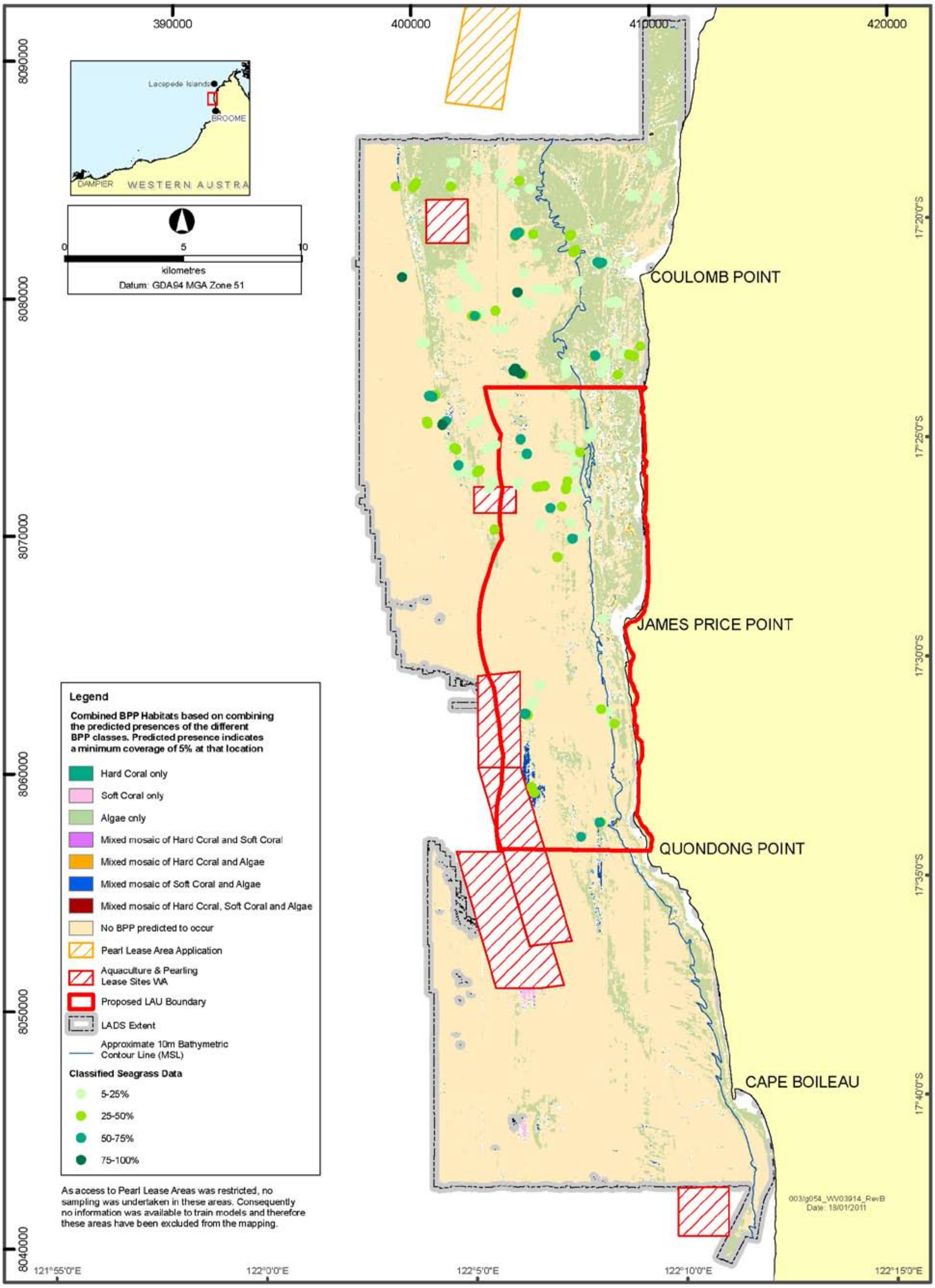
3.3.3. Proposed Local Assessment Unit

An LAU of approximately 120km^2 based on the local ecosystem functionality and geophysical/hydrodynamic processes of the James Price Point coastal area has been defined (**Figure 3-1** and **Figure 3-2**). This proposed LAU encompasses an area running from approximately Flat Rock to Quondong Point (i.e. approximately 20km of coastline). The western boundary is defined by the Western Australian state territorial waters limit (3 nautical miles), and the eastern boundary is defined by the Highest Astronomical Tide (**HAT**) limit. Any smaller scale would necessitate the delineation of two LAUs. In the absence of any clear differences in habitat types, BPP species composition, bathymetry, coastal circulation or ecological connectivity, there is no ecological rationale to define smaller LAUs. Any boundary dividing the area between Flat Rock to Quondong Point would be arbitrary and in conflict with the evidence surrounding ecosystem attributes presented in this document.

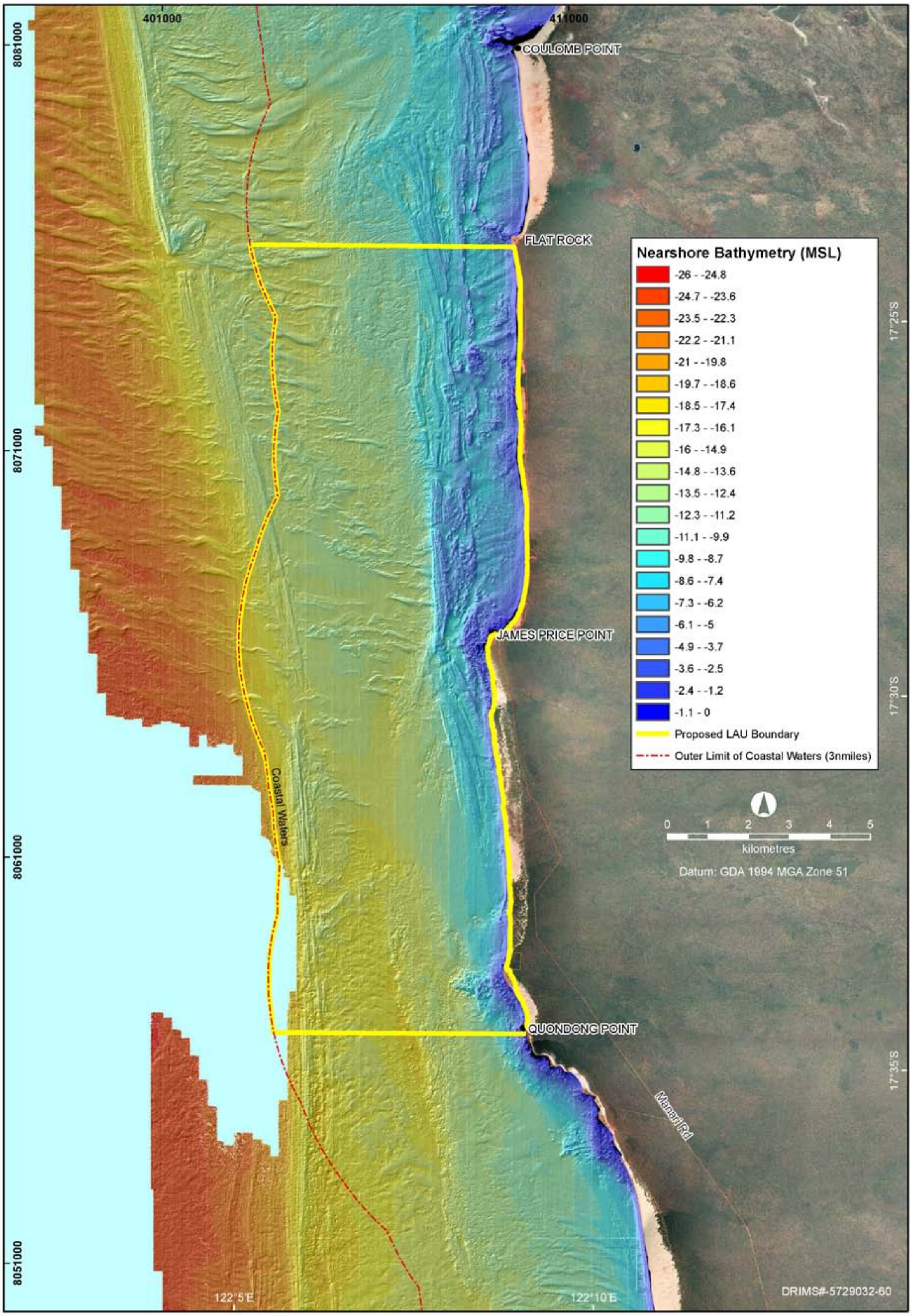
While it is recognised that there are no unique features of this area relative to the larger bioregion, the following points provide a summary of the justification for defining the proposed LAU, which are expanded in sections below.

- There is similar bathymetry (north to south) with representative features from Flat Rock to Quondong Point, extending >7km offshore to the 20m depth contour (slightly beyond the 3 nautical mile State Waters boundary), representing a distinct geomorphological unit.
- A widening of the shelf, combined with a change in the orientation of the coastline and the influence of the ancient remnant coastline, makes the area north of Flat Rock and south of Quondong Point distinctly different to that area occurring between Flat Rock and Quondong Point.
- Large tidal ranges and high current speeds, coupled with periodic natural disturbances (i.e. cyclones), result in a well mixed marine environment (DHI, 2010), suggesting large scale connectivity patterns on at least the scale of the defined LAU.
- Low endemism indicates high connectivity and little isolation amongst benthic species and habitats (DEWHA, 2008), which would otherwise justify smaller LAUs.
- Connectivity studies indicate a minimum of 20km dispersal distance for corals (Underwood *et al*., 2009) and up to 150km for fish and other invertebrates (Palumbi, 2003). This suggests that the defined area from Flat Rock to Quondong Point is sufficient to encompass local scales of connectivity, especially since there is a lack of physical restrictions and/or circulation (e.g. eddy patterns) that would retain larvae within its natal (original) reef.
- Within the proposed LAU, habitats are continuous with no distinct fragmentation that would restrict connectivity.
- Habitat mapping demonstrates that the dominant habitat within the LAU is a ‘mixed mosaic’ of BPPH (comprising primarily of macroalgae, sponges, soft coral, with few hard coral colonies) suggesting no highly distinct subtidal features supporting unique habitat types, such as coral reefs.
- North of Flat Rock, there is a noticeable increase in the density and cover of BPPs, suggesting a shift in environmental and bathymetrical characteristics drives the distribution and cover of biota.
- South of Quondong Point the coastline changes orientation from predominantly north – south to northwest – southeast, with potential changes in exposure and coastal circulation patterns.

While not the primary intent of this study, marine ecosystem level attributes and consequent impact conclusions are discussed in detail in **Part 3**, **Section 2.8** (Marine Ecosystem Integrity).



- **Figure 3-1 The Proposed LAU Overlaid on the Combined Predicted Distribution of BPP (including Seagrass Presence and Percentage Cover) within the James Price Point Coastal Area.**



- **Figure 3-2 The Proposed LAU Overlaid on the Nearshore Bathymetry (Laser Airborne Depth Sounder (LADS) Data).**

3.3.4. Key Ecosystem Attributes

There are relatively consistent geophysical and biological ecosystem attributes (i.e. bathymetry, coastal circulation, habitat connectivity and benthic habitat distribution) throughout the subtidal area between Coulomb Point and Quondong Point. More specifically, an area between Flat Rock (~5km south of Coulomb Point) and Quondong Point was identified as having consistent ecosystem attributes that differentiate the area from surrounding areas north and south of these 'boundaries'.

A detailed discussion on the scale of each ecosystem attribute and how this relates to the justification of the proposed LAU for the Browse LNG Development is provided in the following sections.

3.3.4.1. Bathymetry

The coastline between Flat Rock and Quondong Point runs approximately north to south with no prominent headlands, river mouths or substantial bays. Coastal features are relatively consistent throughout (**Figure 3-2**). Thus, it can be assumed that exposure regimes to swell, currents and terrestrial inputs are also consistent within this stretch of coastline. High resolution bathymetry data (LADS data), collected by Fugro LADS Corporation (Fugro, 2009) using an airborne Light Detection and Ranging (**LiDAR**) bathymetry survey, demonstrated that the underlying bathymetry is relatively uniform in a north to south direction, being typically flat with little topographic complexity, and has no distinctive features, such as islands (**Figure 3-2**). North of Flat Rock there is a change in the bathymetry evident by a widening of the shelf and appearance of the ancient remnant coastline offshore. Similarly, south of Quondong Point there is a change in the orientation of the coastline from a north/south direction to a north-west/south-west direction, north of Barred Creek.

There is an east to west (i.e. inshore to offshore) trend in bathymetry, in terms of depth and physical features. Nearshore seabed contours (down to approximately -20m Chart Datum) run parallel to the shoreline. Further offshore the contours are orientated roughly north-east to south-west (**Figure 3-2**). This trend in bathymetry is consistent along the coastline, with similar depths and bathymetric features represented from approximately Flat Rock to Quondong Point. Thus, the greatest distinction in seabed features exists between the nearshore, shallower areas and those further offshore (beyond the 20m depth contour). There is a gradual change in bathymetry between James Price Point and Coulomb Point evident by a westerly expansion of the nearshore, seabed area and appearance of an inshore beach and cuspate foreland at Flat Rock. This headland represents a northerly boundary, below which is dominated by mostly old ridgelines.

Thus the data suggest that the greatest similarity in bathymetric features exists from Quondong Point to Flat Rock, representing a distinct geomorphological unit and a clear distinction in geomorphological features occur north of Flat Rock (the northern boundary of the proposed LAU) and south of Quondong Point (southern boundary of the proposed LAU). Indeed, the guidelines state that an LAU should generally be defined by features of geomorphology (EPA, 2009).

3.3.4.2. Coastal Circulation

Tides near the James Price Point coastal area are semi-diurnal (two highs and two lows each day), with tidal sea-surface height variability in excess of plus or minus four metres and a tidal range of approximately 7.8m. Tide generated current speeds are in the order of 0.6 metres per second (**m/s**), with speeds reaching close to 1.2m/s nearshore during spring tides. Typically the current tidal regime will display four direction reversals each day in response to the semi-diurnal tides of the region.

Tidal ellipse parameters show a preferentially alongshore north/south flow, induced by tidal currents of 0.1m/s (DHI, 2010). This flow oscillates in a north-north west (**NNW**) direction over the tidal cycle. The combination of strong tides, undulating topography and year round strong solar heating generates a water column that is vertically well mixed with strong topographical forcing. A north/south flow indicates likely water mixing between Quondong Point and Coulomb Point.

Total suspended solids (**TSS**) concentrations derived from Moderate Resolution Imaging Spectroradiometer (**MODIS**) data and *in sit*u loggers at four sites between Coulomb Point and Quondong Point indicated very little variability exists in baseline TSS concentrations between sites, both alongshore and cross shore. This therefore implies a high degree of mixing and homogeneity of water quality among sites within the area.

While the available data do not indicate a distinct difference in coastal circulation patterns between the proposed LAU and areas north or south, it does demonstrate that the coastal hydrodynamic regime within the wider James Price Point

coastal area operates at a scale far larger than the default 50km^2 LAU suggested in EAG3. Therefore, the coastal circulation patterns support the justification for a larger LAU, with distinct boundaries defined by other ecosystem attributes (e.g. bathymetry and BPPH), as presented in this document.

3.3.4.3. Habitat Connectivity

For an adequate assessment of the scale of connectivity within an area, significant consideration should be given to the continuity of habitat type. When habitats are fragmented, the distances between habitat patches become important determinants of the capacity of components of the community to maintain connectivity. Individuals of species unable to bridge those distances by one means or another (i.e. larval dispersion) are, in effect, isolated within their habitat patches. Evidence of isolation can be assessed by comparisons of community assemblages of adjacent habitat patches that are separated from each other by swathes of unsuitable habitat types. If community assemblages are similar in species composition across many different isolated patches, it implies there is sufficient connectivity (through larval dispersion) between those patches to maintain that similarity.

The Canning Bioregion does not support a high degree of biological endemism (DEWHA, 2008), indicating that ecological conditions are not spatially unique and populations are not isolated, with potentially high connectivity (i.e. effective larval dispersal).

Marine larvae of coastal species are commonly observed in mid-ocean plankton, indicating that offshore transport of larvae is a frequent process (Scheltema, 1986) promoting connectivity. Length of larval life varies greatly, but planktonic periods of about a month are common (Grantham *et al.,* 2003). During this time, current flows of 0.1m/s (as discussed in the preceding section) could theoretically move larvae a significant distance downstream. Within the James Price Point coastal area, a month would encompass both a spring and neap tidal cycle, indicating that larvae are likely to be exposed to a high degree of water movement and mixing during their life time (given the north/south along shore flow), thus increasing dispersal. Additionally, Underwood *et al*. (2009) demonstrated that hydrodynamic processes (wind speeds, tidal amplitudes, and strengths of prevailing currents) play an important role in larval dispersal and can influence the distances over which larvae travel and whether they are retained due to circulation patterns. Furthermore, physical links between areas via such processes are likely to play a crucial role in determining the distance of dispersal of larvae (Underwood *et al*., 2007).

For several species of fish and invertebrates with pelagic larvae, isolation-by-distance comparisons suggest mean larval dispersal distances in the order of 25–150km (Palumbi, 2003). In addition, studies have indicated that functional ecological scales of connectivity are in the order of <10-20km (Underwood *et al*., 2009) for areas of isolated shelf atolls along the north-west shelf (Browse Island, Scott Reef and the Rowley Shoals). Thus, these distances are likely to be greater for exposed, coastal areas with limited physical barriers. Local evidence supports this pattern, given that hard coral colonies observed along the benthic video transects were often small, singular colonies in low densities (SKM, 2010a); suggesting that they are frequently subjected to natural disturbances and subsequent recruitment. The persistence of corals on these reefs therefore appears to be dependent at least in part on recruitment of new hard corals into the area by the arrival of larvae from distant reefs.

This data indicates that the scale of connectivity within the James Price Point coastal area is much larger than those implicit within the default 50km^2 LAU discussed in EAG3.

3.3.4.4. Benthic Habitat Distribution

Bathymetry and substrate maps indicate a high degree of consistency in the physical characteristics of the seabed from Flat Rock to Quondong Point. Thus, there appears to be a continuity of major habitats for BPP throughout the area (**Figure 3-1**). The BPPH types between Flat Rock and Quondong Point are dominated by mixed BPP communities (macroalgae, seagrass, filter feeders and hard coral) (SKM, 2010a). Biota coverage is generally sparse, whereas north of Flat Rock there is a distinct change in the density and cover of benthic communities. This is likely driven by a change in bathymetry, with a widening of the nearshore coastal shelf past this point (**Figure 3-2**).

Very few of the BPP communities comprised one distinct type of BPP in isolation, with the exception of some areas of seagrass. These are not likely to comprise unconnected patches of habitat given that seagrass distribution shows considerable variation on both seasonal and inter-annual timescales (SKM, 2010b). There is no evidence that the area comprises patches of habitat that support unique or sensitive communities of individual BPPs. On the contrary, the

evidence suggests there is a widespread mosaic of BPP supported by a largely continuous habitat type throughout the study area, with the intervening areas of unsuitable habitat types not constituting effective barriers to continuity.

3.3.4.4.1. Benthic Habitat Mapping

Given the broad spatial extent for which supporting baseline habitat information was required for the Strategic Assessment Report (i.e. approximately 500km^2), the only practical means to produce detailed and accurate habitat maps was to undertake benthic habitat modelling. Using a combination of high resolution bathymetric data and habitat distribution data (as observed from towed video transects) modelling was used to define the relationships between the environmental conditions (physical characteristics of the seafloor) and the observed distribution of the different habitat classes (i.e. substrate and biota types). By defining these relationships, the models could be used to predict the occurrence of the different habitat classes across the entire area for which the bathymetry data (LADS data; **Figure 3-2**) were available. However, in order to be able to develop robust models for predicting distributions, the habitat class must have been observed with sufficient prevalence (at least 5%). Models developed for habitat classes that were observed with lower prevalence will not be robust as there is insufficient presence data to train the models. In essence, the model would be trained to predict where that biota class would not be found and it would have poor ability to predict presence.

During both the 2008 and 2009 surveys, seagrass was observed with lower prevalence than 5% (3.4% in 2008 and 4.8% in 2009). An attempt to model seagrass distribution was made using the approach described above. However, due to the very low prevalence across the study area, and the highly variable temporal distribution observed between the 2008 and 2009 surveys, a robust relationship between the environmental characteristics and the observed distribution could not be defined. Seagrass was the only habitat class that demonstrated this pattern, with models for other habitat types being relatively consistent across the two sampling periods.

While not conducive to modelling distribution, this result did highlight the highly variable nature of seagrass distribution in the James Price Point coastal area. It also indicated that the spatial and temporal variability of seagrass distribution is less influenced by the environmental characteristics used in this study (e.g. bathymetry and topographic complexity), but more driven by other factors, perhaps seed dispersal or benthic light availability. The conclusion drawn was that seagrass distribution could not be accurately predicted nor mapped. Subsequently, the distribution of seagrass was portrayed using only the observed locations from the towed video transects undertaken in 2008 and 2009 (green dots in **Figure 3-1**) and therefore no area and loss calculations for this assessment were to be derived.

Although it was determined that the modelling of seagrass distribution was not sufficiently accurate or reliable to be incorporated into the benthic habitat maps included in the SAR, an effort has been made to model seagrass distribution for the benefit of undertaking the potential loss calculations as requested by the Office of the Environmental Protection Authority. A description of the methods for determining the area of seagrass within the defined LAU and subsequent loss calculations follows. It should be remembered that the predicted distributions that the loss calculations of seagrass are based on are not considered to be accurate, but provide the best conservative estimate that can be made based on the extensive data collection that has been undertaken (Fry *et al.*, 2008; SKM, 2010b).

The distribution of the benthic habitat classes were predicted based on models developed using all available data (i.e. by combining the data collected in June 2008 by Fry *et al.* (2008) and in November 2009 by SKM (2010b)). When this approach was used to model and predict the distribution of seagrass, it resulted in a very sparse distribution with low accuracy which did not reflect the observed distributions. When the distribution of seagrass was modelled separately using 2008 data and again using 2009 data, the results demonstrated that there were differences in the defined relationships between the environmental characteristics and the observed distribution of seagrass between the two years. Consequently, to take a conservative approach, the overall predicted distribution of seagrass was based on the combined predictions of the model developed using 2008 data and the model developed using 2009 data (only 1% of this combined area was predicted to be seagrass by both the 2008 and 2009 based models). Through this approach, the potential distribution of seagrass from both the 2008 data and the 2009 data was captured. It is considered that this approach will over-estimate the realised niche of seagrass distribution, and therefore, the likely cumulative loss. However, in the absence of an alternative method, it is considered to be the most robust and conservative approach for basing cumulative loss calculations on.

3.4. Calculation of Cumulative Losses of Benthic Primary Producer Habitat

In the context of EAG3, cumulative loss values are the sum of the predicted and historic loss of individual BPPH types within the pre-defined LAU. BPPH are seabed communities within which algae, seagrass, mangroves, corals or mixtures of these groups are prominent components. BPPH also includes areas of seabed that could support these communities (i.e. areas of substrate considered potential habitat). It should be noted that for the purposes of these calculations it has been assumed that the BPPH within the defined LAU has not been subjected to historical losses associated with previous developments. However, this assumption cannot be confirmed for the potential BPPH that occurs within the various pearl leases, as no surveying/mapping was possible within these areas for this study and no published benthic monitoring data is available. The BPPH between Flat Rock and Quondong Point is dominated by a mixed mosaic of BPP (macroalgae, seagrass, and hard coral). Nevertheless, loss calculations were undertaken for the following BPPH categories:

- Intertidal mixed mosaic of coral, algae, and filter feeders;
- Hard coral only;
- Soft coral only;
- Algae only;
- Seagrass only;
- Mixed mosaic of hard coral and soft coral;
- Mixed mosaic of hard coral and algae;
- Mixed mosaic of soft coral and algae;
- Mixed mosaic of seagrass and algae;
- Mixed mosaic of seagrass and hard coral;
- Mixed mosaic of seagrass and soft coral;
- Mixed mosaic of hard coral, soft coral, and algae;
- Mixed mosaic of seagrass, hard coral and algae; and
- Mixed mosaic of seagrass, soft coral and algae.

It should be noted that the ‘only’ categories above have been used to depict areas where the dominant BPP type is found in isolation (i.e. not in a mosaic with other BPP). For example, the area calculated for the ‘soft coral only’ category does not include soft coral within the ‘mixed mosaic of soft coral and algae category’ and vice versa.

The presence/absence of BPPH within the James Price Point coastal area (excluding the substrate beneath the various pearl leases) has been surveyed and mapped previously (**Figure 3-1**). Subtidal BPPH (habitat up to the lowest astronomical tide (**LAT**)) was modelled and mapped within the spatial extent of the LADS bathymetric data (**Figure 3-2**) (SKM 2010a; **Appendix C-5** of the Strategic Assessment Report). BPPH between the LAT and HAT were mapped based on the results of intertidal survey surveys (SKM, 2010c and SKM, 2010d).

BPPH types that were defined and mapped, from which loss calculations were determined, include algae, hard coral, and photosynthetic soft coral and seagrass. A brief description of the approach taken and methods used to calculate the total cover (area) of the defined BPPH type and subsequent cumulative losses attributable to the BLNG Development activities within the LAU is outlined below, with a more detailed description provided in **Appendix G-2**: Benthic Primary Producer Habitat Loss Calculations.

The intertidal BPPH extent and subsequent loss calculations were based on a combined BPPH class as insufficient detail was available in the survey data to allow partition into individual categories.

It should be noted that the subtidal habitat models predict where it is likely that BPPH may be present given the environmental characteristics that occur at a particular location (i.e. they predict where there are suitable environmental conditions for BPP based on observed distributions). For these predictions, a location is defined by the spatial extent of a 6 x 6m cell in the collected bathymetry data (i.e. the spatial resolution of the data). Therefore habitat maps of BPPH derived from the model represent areas of both actual and potential habitat distribution (i.e. the realised niche), as opposed to simply distribution at the time of survey. It should also be noted that the calculations do not take into account potential BPPH within the pearl leases, as access to these areas was restricted during surveys of the area. The

calculations and associated BPPH mapping may be updated to reflect potential BPPH within these areas in order to inform the derived proposals, if access is granted.

The BPPH loss calculations were applied based on the direct footprints associated with the following infrastructure scenarios/components, each with a surrounding Zone of High Impact (permanent loss) derived from the sediment transport modelling of the turning basin point source discharge outlined in the SAR:

1) *Scenario 1:* An ‘indicative’ port development scenario (pink dashed line in **Figure 3-3**). This scenario consists of a potential port layout and shipping channel configuration, and corresponds to Layout Option A depicted in **Part 3**, **Figure 2.4-2**. This development scenario occupies only a proportion of the ‘whole’ port development scenario detailed below.
2) *Scenario 2:* The ‘whole’ port development area scenario (blue dashed line in **Figure 3-3**). This scenario consists of infrastructure occupying the entire port precinct area and shipping channel corridor and corresponds to that depicted in **Part 3**, **Figure 2.4-2**.
3) *Scenario 3:* The southern pipeline corridor (southern green dashed line in **Figure 3-3**). This corresponds to **Part 3**, **Figure 2.4-5**.
4) *Scenario 4:* The northern pipeline corridor (northern green dashed line in **Figure 3-3**). This corresponds to **Part 3**, **Figure 2.4-5**.

3.4.1. Subtidal Calculation Methodology

The area of loss of each BPPH type (algae, hard coral, macroalgae, soft coral, seagrass, and BPP mosaics) within the subtidal area was calculated via the following steps.

1) The predicted distribution of individual BPPH types were combined to produce a map showing a) areas of consistent BPPH category (e.g. hard coral community); and b) areas of mosaic (e.g. mixed mosaic of soft coral and algae).
2) The number of cells in the LAU and the subtidal Zones of High Impact that were predicted to contain each BPPH category or BPPH mosaic was determined.
3) Areal coverage of each BPPH category or mosaic in each zone was determined by multiplying the cell count by the LADS data cell size ($36m^2$).
4) The ‘predicted loss area’ was then determined by calculating the areal extent of each BPPH category/mosaic in each of the Zones of High Impact as a proportion of the area of each BPPH category/mosaic in the LAU.

3.4.2. Methodology of Intertidal Calculations

The area of loss of BPPH (combined category) within the intertidal area was calculated via the following steps:

1) The boundaries of distinct intertidal zones were delineated using geo-referenced high resolution aerial images and bathymetry data.
2) Data from the intertidal baseline study was then used to assign a habitat classification to the intertidal zones.
3) For those intertidal zones that contained BPPH (intertidal combined BPPH), the areal coverage was calculated in the Geographic Information System (**GIS**).
4) The ‘predicted loss area’ was then determined by calculating the areal extent of the intertidal combined BPPH category in each of the Zones of High Impact as a proportion of the intertidal BPPH mosaic in the entire LAU.

The extent of BPPH and the cumulative percentage loss in each category is presented in **Table 3-1** and **Table 3-2** respectively.

3.4.3. Results

- **Table 3-1 Benthic Primary Producer Habitat (BPPH) Extent (hectares).**

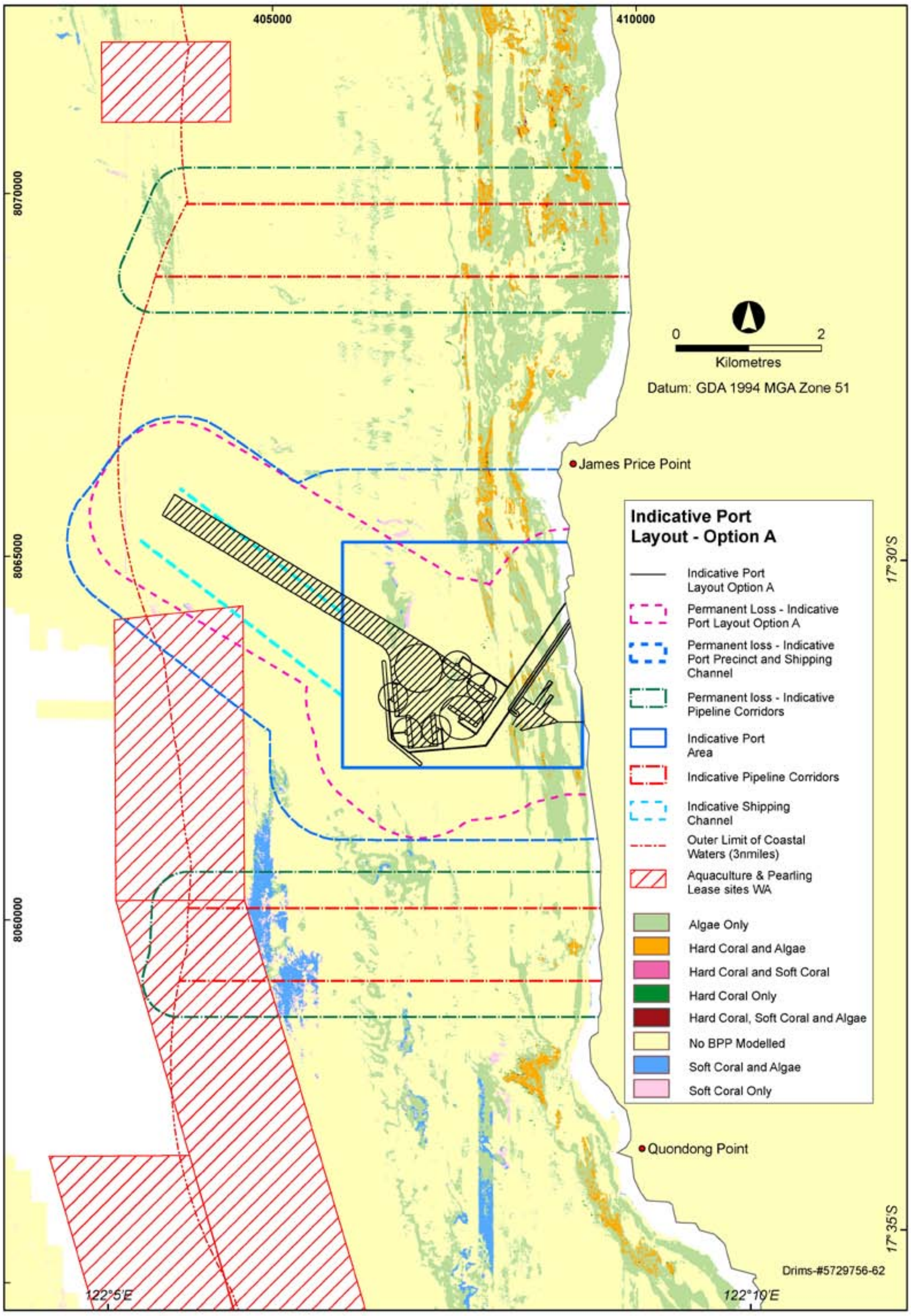
BPPH Category	LAU (ha)	Indicative port development scenario (1) (ha)	Whole port development area scenario (2) (ha)	Southern pipeline corridor (3) (ha)	Northern pipeline corridor (4) (ha)	Component/Scenario Totals (ha)			
						1+3	2+3	1+3+4	2+3+4
Total BPPH	3314.3	321.1	525.1	262.1	350.2	583.2	787.2	933.4	1137.4
Intertidal mosaic of coral, algae and filter feeders	372.10	34.44	68.51	8.21	14.57	42.65	76.72	57.22	91.28
Hard coral only	6.76	0.46	0.72	0.12	1.08	0.58	0.84	1.65	1.91
Soft coral only	115.03	5.53	19.19	13.78	0.83	19.30	32.97	20.13	33.80
Macroalgae only	1707.18	164.46	251.98	86.90	261.21	251.36	338.88	512.57	600.09
Seagrass only	514.29	96.69	138.72	78.18	33.99	174.87	216.89	208.86	250.88
Mixed mosaic of hard coral and algae	269.80	15.56	36.01	2.36	33.21	17.92	38.37	51.14	71.59
Mixed mosaic of soft coral and algae	127.0	1.0	2.12	29.46	0.15	30.46	31.59	30.61	31.73
Mixed mosaic of hard coral and soft coral	0.18	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
Mixed mosaic of hard coral, soft coral and algae	2.76	0.00	0.19	0.02	0.20	0.02	0.21	0.22	0.40
Mixed mosaic of Seagrass and Algae	143.02	2.12	5.87	6.14	4.54	8.26	12.01	12.80	16.55
Mixed mosaic of Seagrass and Hard Coral	1.76	0.07	0.08	0.00	0.37	0.08	0.09	0.44	0.45
Mixed mosaic of Seagrass and Soft Coral	14.23	0.72	1.40	8.74	0.04	9.46	10.14	9.50	10.18
Mixed mosaic of Seagrass, Hard Coral and Algae	5.19	0.02	0.03	0.00	0.01	0.02	0.03	0.03	0.03
Mixed mosaic of Seagrass, Soft Coral and Algae	34.89	0.02	0.24	28.21	0.00	28.23	28.45	28.23	28.45

- **Table 3-2 Cumulative Percentage Loss of LAU BPPH (percent).**

BPPH Category	Indicative port development scenario (1) (%)	Whole port development area scenario (2) (%)	Southern pipeline corridor (3) (%)	Northern pipeline corridor (4) (%)	Component/Scenario Totals (%)			
					1+3	2+3	1+3+4	2+3+4
Combined BPPH	9.7	15.8	7.9	10.6	17.6	23.8	28.2	34.3
Intertidal mosaic of coral, algae and filter feeders	9.3	18.4	2.2	3.9	11.5	20.6	15.4	24.5
Hard coral only	6.8	10.7	1.7	15.9	8.5	12.4	24.5	28.3
Soft coral only	4.8	16.7	12.0	0.7	16.8	28.7	17.5	29.4
Macroalgae only	9.6	14.8	5.1	15.3	14.7	19.9	30.0	35.2
Seagrass only	18.8	27.0	15.2	6.6	34.0	42.2	40.6	48.8
Mixed mosaic of hard coral and algae	5.8	13.3	0.9	12.3	6.6	14.2	19.0	26.5
Mixed mosaic of soft coral and algae	0.8	1.7	23.2	0.1	24.0	24.9	24.1	25.0
Mixed mosaic of hard coral and soft coral	0	2.0	0	6.0	0	2.0	6.0	8.0
Mixed mosaic of hard coral, soft coral and algae	0	6.8	0.7	7.2	0.7	7.4	7.8	14.6
Mixed mosaic of Seagrass and Algae	1.5	4.1	4.3	3.2	5.8	8.4	9.0	11.6
Mixed mosaic of Seagrass and Hard Coral	4.1	4.7	0.2	20.9	4.3	4.9	25.2	25.8
Mixed mosaic of Seagrass and Soft Coral	5.1	9.8	61.4	0.3	66.5	71.3	66.8	71.5
Mixed mosaic of Seagrass, Hard Coral and Algae	0.4	0.5	0	0.1	0.4	0.5	0.6	0.6
Mixed mosaic of Seagrass, Soft Coral and Algae	0.1	0.7	80.9	0	80.9	81.6	80.9	81.6

Note: - The calculations do not take into account potential BPPH within the pearl leases, as access to these areas was restricted during surveys of the area.

- Cells shaded green show cumulative loss less than EAG3 guideline level, while cells shaded orange indicate exceedance of the guideline threshold.



- **Figure 3-3 Predicted Zone of High Impact (i.e. Permanent Loss) for the Indicative Port Concept (Layout Option A in SAR and Scenario 1 in this Context) and the 'Whole' Precinct Port Development Area including Shipping Channel (Scenario 2) and Pipeline Corridors (Scenarios 3 and 4).**

Note The areas shaded white along the coastline represent the intertidal zone, which was not mapped as part of the subtidal BPPH mapping study. Subtidal BPPH (habitat up to the lowest astronomical tide was modelled and mapped within the spatial extent of the LADS bathymetric data. Potential BPPH between the Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT) (i.e. the white shaded areas) were mapped based on the results of a separately conducted intertidal survey and have been included in the calculations of predicted BPPH loss (**Section 3.4.2**). This corresponds to the BPPH category of 'intertidal mosaic of coral, algae and filter feeders' presented in **Table 3-1** and **Table 3-2**.

3.5. Assessment against SAR Impact Conclusions and Outcomes

Application of EAG3 involves area calculations for the existing impact predictions in the SAR. Therefore its application does not alter the SAR impact conclusions and outcomes which already considered the ecological and social implications of the BPPH loss predicted.

3.5.1. Predicted Impacts

3.5.1.1. Environmental Factors

The EPA has determined cumulative loss guidelines for BPPH that are based on land use and ecosystem attributes (**Table 3-3**). As the Browse LNG Precinct is intended as a large coastal port development within which future development will be aggregated, it would be classified as a category E area (i.e. "...*where the land use has been designated for heavy industry, large coastal proposals or related purposes by a State Government decision..."* (EPA, 2009). The Cumulative Loss Guideline (**CLG**) associated with this category (10% cumulative loss) therefore applies.

- **Table 3-3 Cumulative Loss Guidelines for BPPH within Defined LAUs for Six Categories of Marine Ecosystem Protection.**

Category	Description	Cumulative loss guideline
A	Extremely special areas	0%
B	High protection areas other than above	1%
C	Other designated areas	2%
D	Non-designated area	5%
E	Development areas	10%
F	Areas where cumulative loss guidelines have been significantly exceeded	No net damage/loss

The BPPH extent calculations (**Table 3-1**) support many observations made in the SAR. For example, the dominance of macroalgae communities in the JPP nearshore marine environment is evident in that the 'macroalgae only' category makes up 52% of BPPH in the LAU. By contrast, the 'hard coral only' category makes up only 0.2% of the BPPH in the LAU.

The indicative port development scenario (1) does not result in exceedance of the Category E 10% loss guideline for any BPPH categories apart from 'seagrass only', and equates to a loss of 9.7% of combined BPPH in the LAU (**Table 3-2**). Addition of the southern pipeline corridor planned for the Foundation Project results in exceedance of the Category E 10% loss guideline for 'soft coral only' (16.8%), 'macroalgae only' (14.7%), seagrass only (34%) and 'mixed mosaic of soft coral and algae' (24%), 'mixed mosaic of seagrass and soft coral (66.5%) and 'mixed mosaic of seagrass, soft coral and algae (80.9%). This equates to a loss of 17.6% of combined BPPH in the LAU. Addition of the northern pipeline corridor (4) results in exceedance of the 10% loss guideline for all the BPPH categories with the exception of the 'mixed mosaic of hard coral and soft coral', 'mixed mosaic of hard coral, soft coral, and algae', 'mixed mosaic of seagrass, hard coral and soft coral', and 'mixed mosaic of seagrass and algae' categories.

When considering these proportions, it must be noted that the total extent of BPPH in the LAU is relatively low (approximately 72% of the LAU contains no BPPH), therefore any impact on BPPH in the LAU is likely to constitute a large proportion of the total. The low BPPH loss calculations for the indicative port development scenario (1) reflect the site selection process undertaken for the Browse LNG Precinct, in which the area south of James Price Point was selected due to the limited BPPH in this area.

As outlined in the SAR, the impact zones associated with the pipeline corridors have been based on the assumption that the most invasive construction technique (open cut trenching/dredging followed by backfill) will be required for ≤3 nautical miles of the nearshore pipeline route. In addition to the fact that less invasive techniques are being considered for the nearshore pipeline routes (refer to **Part 3**, **Section 2.4.3.1**); application of a Zone of High Impact to pipeline dredging works is considered extremely conservative. Pipeline trenching/dredging activities typically involve smaller volumes, occur over shorter timeframes, and result in significantly smaller zones of influence and impact than dredging for shipping infrastructure. For example, the zone of water quality influence around pipeline dredging works for the Pluto LNG Project was approximately 500m (versus 3-5km for the turning basin and channel), and the Pluto LNG Project

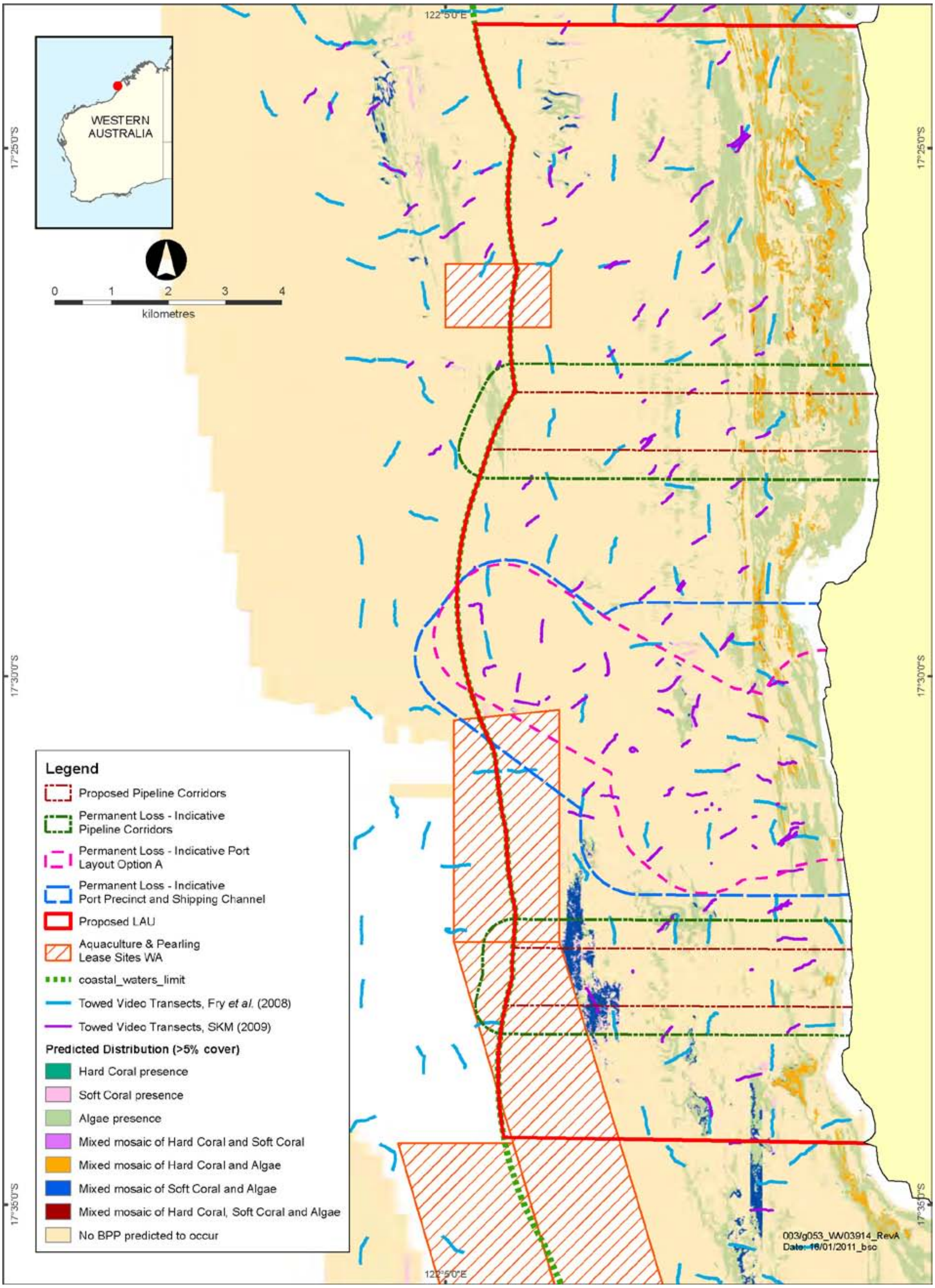
pipeline works had no impact on coral communities outside the direct footprint of the trench. At this stage of the assessment, detailed modelling to simulate these less intensive dredging works is not available, however it is anticipated that modelling for derived proposals will result in smaller footprints for the pipeline corridors.

It must also be noted that there has been limited ground truthing conducted (via towed video) through the area of soft coral and algae mapped at the western end of the southern pipeline corridor (**Figure 3-3**) due to access restrictions associated with the pearling leases (refer to **Figure 3-4**). Through this area, the mapping is therefore relying entirely on model predictions based on bathymetry. Options for further ground truthing to confirm the presence/absence of soft coral in this area are currently being investigated to inform future derived proposals.

As presented in **Section 3.4**, the loss calculations for BPPH categories vary between the indicative port development Scenario (1) and the conservative whole port development Scenario (2). For the whole port development area Scenario (2), the Category E 10% loss guideline is exceeded for the 'combined BPPH', 'intertidal mosaic of coral, algae and filter feeders', 'soft coral only', 'macroalgae only', ' hard coral only, 'seagrass only' and 'mixed mosaic of hard coral and algae' (**Table 3-2**). Exceedance of categories containing macroalgae components is not unexpected given the dominance of macroalgae habitat in the region. Whilst removal of macroalgal habitat is expected to permanently reduce benthic primary production in the area, this is not expected to impact on general ecosystem function and integrity of the LAU, given the prevalence of this habitat type within the wider bioregion (e.g. north of Coulomb Point and south of James Price Point at Gourdon Bay). The implications of the predicted losses associated with seagrass and the potential consequent effects on dugong populations within the Dampier Peninsula have been detailed in **Part 3**, **Section 2.6.3.2** (Marine Mammals). The results of the loss calculations (**Table 3-2**) detailed in this supplement are considered consistent with the impact assessment conclusions and environmental outcomes discussed in the Strategic Assessment Report.

As outlined in the SAR, it is considered unlikely that infrastructure would occupy the entire port development area; however the location of the port layout may vary within the port development area, therefore the whole port development area boundaries need to be retained for strategic impact assessment purposes.

The initial impact assessment conclusions within the Strategic Assessment Report were conservative and acknowledged the predicted permanent loss of BPPH within the Zone of High Impact. While this supplementary assessment has placed the predicted impacts into context within a defined LAU, the environmental outcomes of the proposed nearshore construction activities remain consistent with those presented within **Part 3**, **Section 2.4.5** (Benthos) and **Section 2.8.5** (Marine Ecosystem Integrity).



- **Figure 3-4 Overlay of the Extent of Towed Video Survey Transects with the Predicted Zone of High Impact (i.e. Permanent Loss) for the Indicative Port Concept (Layout Option A in SAR and Scenario 1 in this Context) and the 'Whole' Precinct Port Development Area including Shipping Channel (Scenario 2) and Pipeline Corridors (Scenarios 3 and 4).**

3.5.1.2. Social Factors

The potential loss of Benthic Primary Producer Habitat, particularly during port construction, and the related marine environmental impacts is an important community issue, particularly among customary, commercial and recreational fishers. Customary fishing practices use a range of marine food species to significantly supplement the diet of Aboriginal people on the Dampier Peninsula. Commercial fishing is an important industry in the Broome/Dampier Peninsula region and includes managed commercial fisheries (including mackerel, demersal scale fish, prawns, beche de mer and gillnet operations) as well as specimen shell and marine aquarium fish collectors. There are also multiple pearl farm leases in the area with the closest owned by Clipper Holdings Pty Ltd (Clipper Pearls) which is approximately 4-5km west of James Price Point. While aquaculture does not occur in the vicinity of James Price Point, both marine and on-shore recreational fishing (including customary fishing) are popular pastimes.

Potential loss of BPPH in and near to the vicinity of pearling lease areas and recreational and commercial fishing areas may have an impact on the water quality and feeding/nursery opportunities available to pearl oysters, recreational and commercial fish species.

As discussed in **Part 5**, **Section 4.5** (Commercial Fishing) and **Part 4**, **Section 3.8** (Customary Fishing) there is the potential for the BLNG Precinct to impact on customary, recreational and commercial fishing due to dredging during construction and ongoing maintenance. This activity may increase sedimentation which may potentially disturb local fishing activities. **Part 5**, **Section 4.5** concludes that, based on currently available information, the activities of commercial fishers are unlikely to be significantly affected by the development of the Precinct over the long term. **Part 5**, **Section 4.6** (Aquaculture and Pearling) points out that the species of oyster utilised in the pearling industry (*Pinctada maxima*) has a relatively high tolerance to turbid environments. **Part 5**, **Section 4.6** reports that the levels of TSS in areas leased for pearling, with the exception of the northern-most section of the Clipper Pearls lease, are not expected to increase above the range of tolerance of *P.maxima*. **Part 5**, **Section 4.8** (Sports, Recreation (including recreational fishing) and Land Use) highlight that the land and sea areas around James Price Point are utilised for recreational boating and fishing, particularly for Broome residents. Disturbance to BPPH may impact on the marine recreation activity. The findings of this benthic study are consistent with those in the SAR.

According to the Aboriginal Social Impact Assessment (**ASIA**), ethno-biological and customary fishing studies (see **Part 5**, **Section 3.4**, **Section 3.7** and **Section 3.8**) turtle and dugong continue to be highly prized resources and mangrove areas provide a variety of resources, including shellfish, mud crabs, mangrove worms and mullet. Mangrove ecosystems do not occur in the vicinity of James Price Point, so impacts on this BPP type are not anticipated. The results of this study, to assess the BPPH loss calculations of the proposed BLNG Precinct infrastructure in the context of a defined LAU, do not change the impact conclusions or management response proposed in the ASIA section of the SAR.

3.5.2. Mitigation and Management

This supplementary assessment does not alter the environmental impact predictions originally presented within the SAR, rather it provides more detail on the estimated extent of BPPH likely to be impacted and places this into context within a defined LAU. The measures outlined within **Part 3**, **Section 2.4.4** (Benthos) and **Section 2.8.4** (Marine Ecosystem Integrity) are considered to be appropriate in mitigating and managing the predicted environmental impacts to an acceptable level.

The social outcomes determined from the benthic study are consistent with those originally presented within the Strategic Assessment Report. The key mitigation and management measures are summarised in the SAR. These mitigation measures include a requirement that, prior to commencement of dredging, proponents of derived proposals shall prepare and implement a Dredging and Dredge Spoil Disposal Management Plan (**DSDMP**), to the satisfaction of the Western Australian Minister for Environment, demonstrating the application of best practice management techniques and technologies to minimise potential dredging impacts. The implementation of these measures will ensure that social outcomes are achieved.

3.6. Conclusion

As outlined in Environmental Assessment Guideline 3 (EPA, 2009) "cumulative loss guidelines... are not intended to be applied as rigid limits. Cumulative loss guidelines represent a level of cumulative loss that, if not exceeded, is unlikely to pose unacceptable risk to ecological integrity." Exceedance of the CLGs is intended to prompt a closer examination of the potential ecological significance of the impact to ensure that the development will not pose an unacceptable risk to ecological integrity. As per Environmental Assessment Guideline 3 (EPA, 2009), it is noted that the acceptability of any permanent loss of BPPH will remain the judgement of the EPA, based primarily on the overall risk to ecological integrity within the local assessment unit.

The first overarching environmental protection principle defined in Environmental Assessment Guideline 3 (EPA, 2009) is that "all proponents should demonstrate consideration of options to avoid damage/loss of benthic primary producer habitats, by providing the rationale for selection of the preferred site and broad project design". In accordance with this principle and as a result of a robust site selection process (refer to **Part 2**, **Section 4**), the site chosen for the BLNG Precinct was strategically placed to avoid areas of significant benthic habitat. This resulted in the choice of a site where, within the defined LAU encompassing the BLNG Precinct, BPPH coverage is generally low (approximately 72% of the LAU contains no BPPH) and thus for the Indicative Port Development (scenario 1) only 9.7% of BPPH in the LAU is predicted to be permanently lost.

Application of the conservative sediment transport modelling process outlined in the SAR to pipeline dredging activities is highly likely to overestimate the scale of impact associated with these works. Though the predicted losses associated with the pipeline corridors (components 3 and 4) result in exceedance of the cumulative loss guidelines, and have been determined to be permanent for the purpose of the assessment; the use of sand backfill and/or rock armouring around the nearshore approach of the pipelines is likely to result in recolonisation by a range of BPP communities (as has been observed elsewhere on the North West Shelf). This recolonisation may therefore 'offset' some of the loss predicted to occur as a result of the development.

As BPPH extent within the LAU is low, any predicted losses of BPPH would be disproportionately high compared to the magnitude of losses that may occur if the development was sited elsewhere along the coastline, where BPPH is more common. Additionally, the majority of BPPs recorded within the LAU consist of a mosaic of mixed BPP taxa, with no evidence to suggest that the LAU contains significant patches of habitats that support distinct or unique community types. For example, distinct hard coral-dominated patches comprised less than 0.2% of BPPH within the LAU. Therefore, any BPP communities that may suffer losses within the LAU are well represented elsewhere within the bioregion. With a high level of continuity and connectivity among BPPH areas within the bioregion, it is likely that key fauna (e.g. dugongs) would be able to re-locate to other areas if affected by BPPH impact associated with the development.

Therefore, despite predictions that the LAU cumulative loss guidelines may be exceeded, the actual magnitude of predicted losses of BPP communities is relatively low and BPP types that may suffer losses are common within the wider bioregion. Hence, the risk to the ecological integrity of the marine environment within the LAU is considered to be low.

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4. Hydrocarbon Spill Modelling

4.1. Introduction

The Strategic Assessment Report (**Part 2**, **Section 5**) provides an overview of the BLNG Precinct and the types of hydrocarbon inventories anticipated to be required for a full development 50Mtpa scenario. To enable the production of LNG, raw hydrocarbons from the gas fields of the Browse Basin would be transported to the Precinct via subsea pipelines. Onshore within the Precinct, the gas would be processed, liquefied and stored, prior to being loaded onto purpose-built ships for transport to market. Condensate (a light crude oil) would be separated from the incoming gas stream, treated, stored and loaded into tankers for transport to Australian or international markets. Liquefied Petroleum Gas (**LPG**), comprised largely of propane and butane, may also be produced within the gas processing facilities located within the Precinct.

A number of hydrocarbon liquids will be stored within the BLNG Precinct area such as LNG, condensate, marine diesel, lube oil. Bunker fuel is used as fuel for some ships transiting through the ports noting that LNG tankers are generally gas powered. These are further described in **Part 2**, **Section 5** (Description of Activities and Facilities), and formed the basis of the impact assessment for non-routine discharges.

Throughout the construction and operational phases of the BLNG Precinct, there is a potential for these liquids to discharge into the surrounding marine environment. Minor hydrocarbon or chemical discharges may result from unplanned events such as process leaks and small operational spills, which typically result in negligible environmental impact. Major hydrocarbon discharges, such as those which could result from vessel collisions, rupture of an LNG/condensate tanker or catastrophic failure of a production pipeline, could result in the rapid release of a large volume of hydrocarbons. Whilst the likelihood of an event of this nature occurring is considered to be 'highly unlikely', the environmental and social consequences could be significant.

The impact assessment conclusions related to non-routine marine discharges are provided in **Part 3** (Environmental Assessment – Marine Impacts), and social factors are considered in **Part 5** (Social Assessment). The following section provides a summary of the results of hydrocarbon modelling undertaken to inform the SAR Supplement, specifically to determine whether the predicted impacts are manageable and corresponding management measures appropriate, in the context of the BLNG Strategic Assessment.

4.2. Relevant Factors

4.2.1. Environmental Factors

The results of the hydrocarbon spill modelling are primarily relevant to the following environmental factors:

- Marine Sediments (**Part 3**, **Section 2.2**);
- Marine Water Quality (**Part 3**, **Section 2.3**);
- Benthos including Benthic Primary Producers (**Part 3**, **Section 2.4**); and
- Marine Ecosystem Integrity (**Part 3**, **Section 2.8**).

4.2.2. Social Factors

The study conclusions for hydrocarbon spill modelling are primarily relevant to the following social factors:

- Visual Amenity, Light and Landscape Character (**Part 5**, **Section 4.4**);
- Commercial Fishing (**Part 5**, **Section 4.5**);
- Aquaculture and Pearling (**Part 5**, **Section 4.6**);
- Tourism (**Part 5**, **Section 4.7**);
- Sports, Recreation (including recreational fishing) and Land Use (**Part 5**, **Section 4.8**); and
- Customary Fishing (**Part 5**, **Section 3.8**).

Other factors of less potential significance have been identified, and are addressed in consideration of the primary factors above. These other factors are:

- Species of Ethno-biological Significance (**Part 4**, **Section 2.5**); and
- Potential Socio-Economic Impacts on Indigenous People (**Part 5**, **Section 3.4**).

4.3. Study Overview

4.3.1. Objectives

The hydrocarbon spill modelling was undertaken to meet the following key overall objectives:

- to present the modelling process undertaken for a number of hydrocarbon spill scenarios;
- to predict the combined probability of spills from all scenarios impacting on critical environmental assets;
- to estimate the scale of response times required to address spills of different sizes;
- to confirm the impact conclusions described in the SAR; and
- to assess the suitability of proposed management measures defined in the SAR.

4.3.2. Methodology Overview

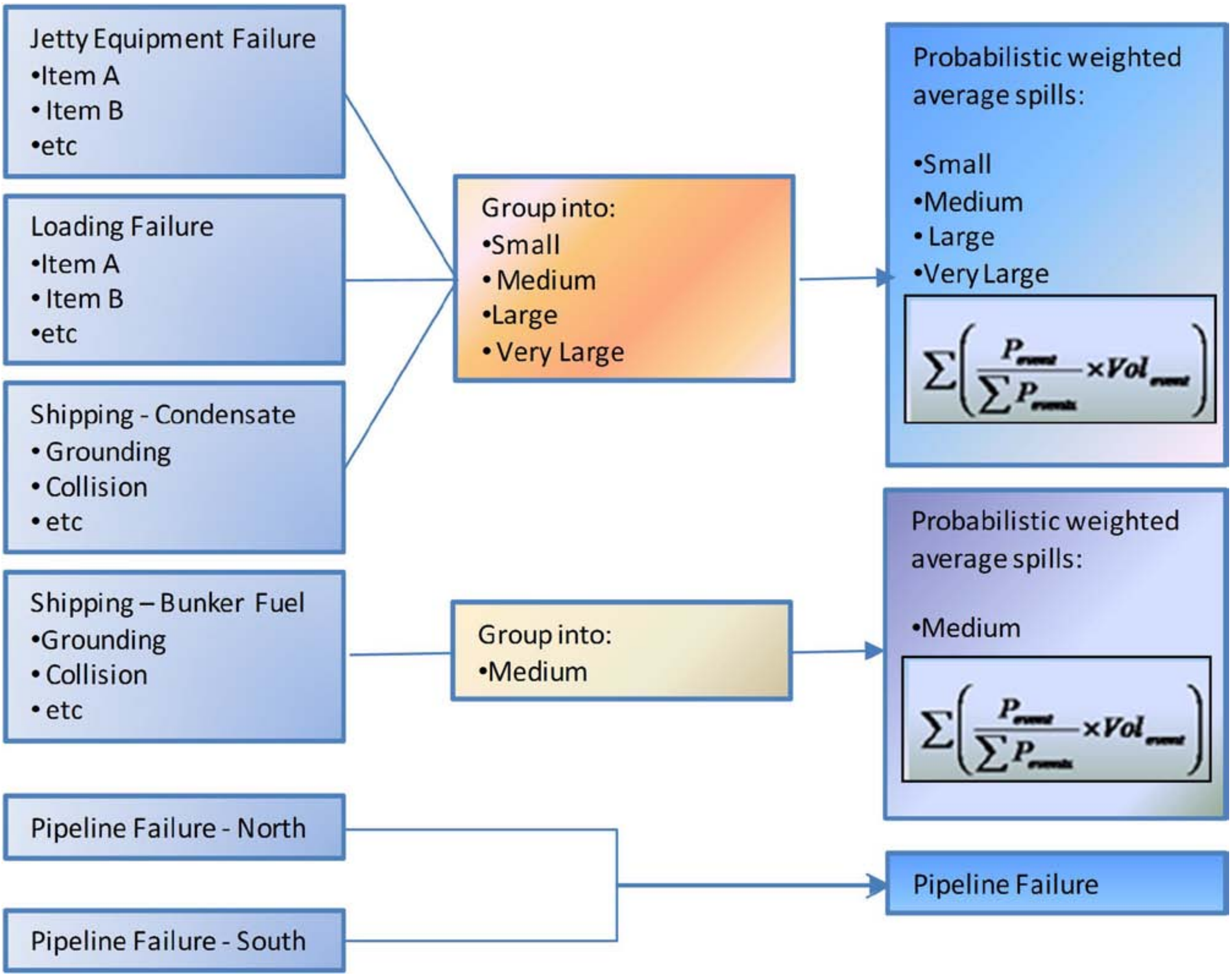
A hydrocarbon modelling study was undertaken by DHI Water and Environment (DHI, 2011b, **Appendix G-3**) to simulate the possible impacts of hydrocarbon spills from the BLNG Precinct development, in order to inform the Strategic Assessment. A summary overview of the approach is presented below, with further details included in **Appendix G-3**.

In order to capture the risk of a spill combined with the likely consequence for the environment a range of potential spill events were considered. It was determined that the primary risks of spills were associated with Port operations (condensate loading system, ship handling and ship loading) and loss from the condensate pipeline(s) within 3 nautical miles (Nm) of the coast.

Key steps in the process used were:

- quantify all identifiable events (using Quantitative Risk Assessment (**QRA**) methodology);
- group these into 'representative events' based on spill type, spill volume and likelihood of occurrence (event probability);
- model these 'representative events';
- plot results showing combined event probability and environmental fate probability; and
- sum all events into a single probability map.

Figure 4-1 presents the process undertaken to rationalise the multiple potential sources of spills into 6 statistically representative spills to enable spill modelling to be undertaken. Utilisation of this approach enabled the consolidation of all identifiable spill sources into seven representative scenarios. The very large spill was not carried forward as the probability of the event occurring is very remote (at once every 700,000 years for the facility), leaving six representative scenarios that were modelled (**Table 4-1**).



- **Figure 4-1** **Schematic Diagram of the Approach Taken to Determine the Probability of a Range of Spill Events to Rationalise Representative Spill Scenarios as Basis of Modelling.**

Note: In the formula above for probabilistic weighted average spill, read the subscript as "event".

This analysis resulted in the modelling of six representative scenarios using a Combined Probability approach:

- 2 condensate pipeline loss scenarios;
- 3 port condensate loss scenarios; and
- 1 Port bunker fuel scenario.

A summary of assumed spill characteristics for each scenario is presented in **Table 4-1**.

- **Table 4-1 Key Characteristics of the Six Hydrocarbon Spill Scenarios Modelled.**

ID	Description	Location	Event Frequency for the Precinct Port	Release Rate (m^3/hr)	Duration (hrs)	Spill Volume (m^3)
Pipeline Condensate Releases						
1	Pipeline failure	Northern pipeline	Once every 700 years	152	336	52,000
2	Pipeline failure	Southern pipeline	Once every 700 years	152	336	52,000
Port Condensate Releases (including ships in port)						
3	Small (1-100m^3)	Port	Once every 60 years	N/A	Instant	25
4	Medium (101-1,000m^3)	Port	Once every 4,000 years	N/A	Instant	270
5	Large (1001-10,000m^3)	Port	Once every 17,000 years	N/A	Instant	8,700
Port Bunker Fuel Hydrocarbon Release (including ships in port)						
6	Accidental spillage	Port	Once every 12,000 years	N/A	Instant	4,500

Source: DHI (2011b; Table 3).

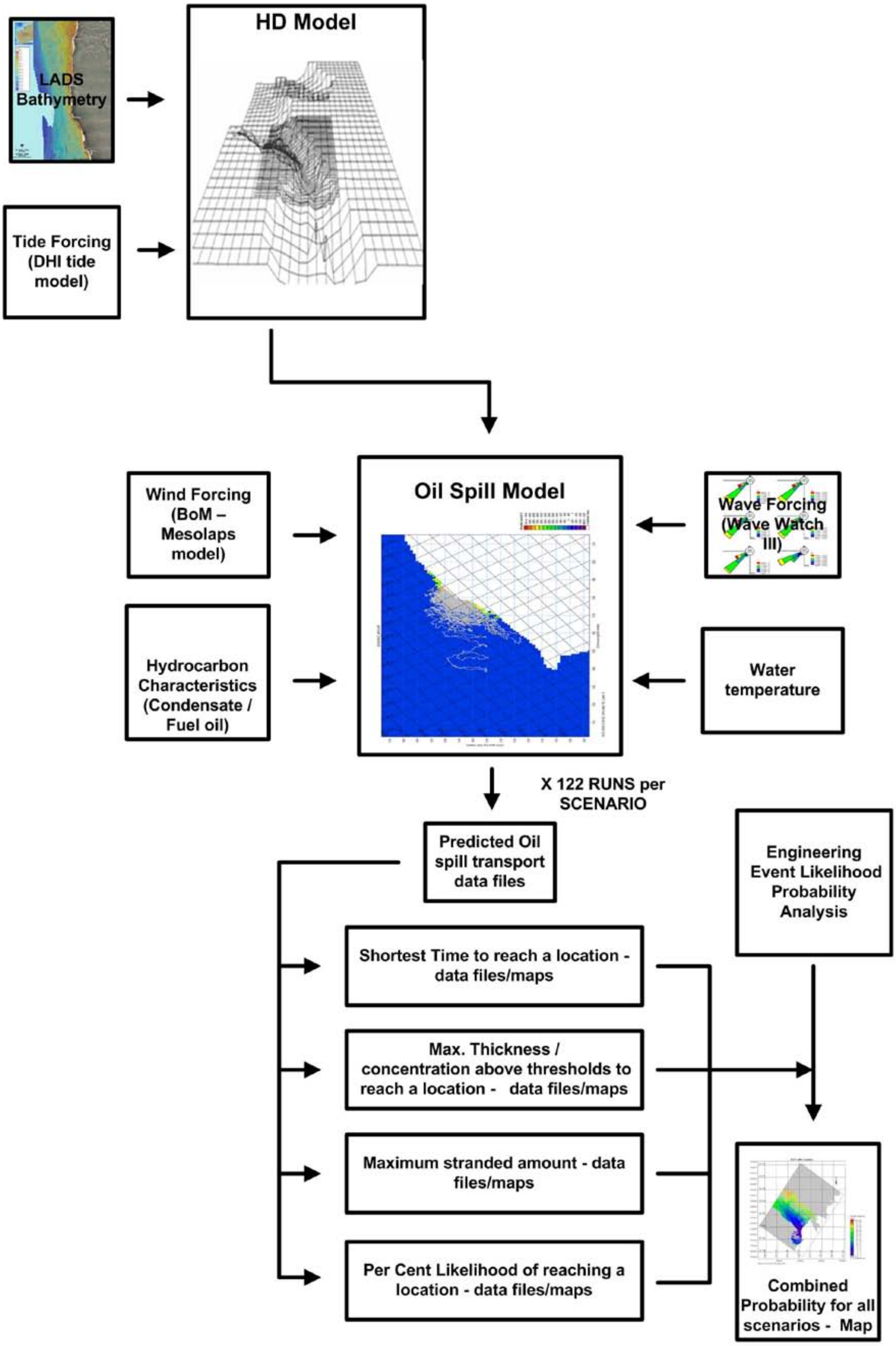
The assessment methodology used conservative assumptions including: assessment based on a full scale 50Mtpa development; conservative (high) initiating event likelihoods; no allowance for spill response or containment of spills after the initiating event (i.e. larger than anticipated volumes released); and conservative modelling assumptions (i.e. greater spread of hydrocarbons than would actually be expected). These factors in combination are likely to overstate the predicted impacts of hydrocarbon spills on the Kimberley region.

Each of the representative scenarios were each modelled 122 times (i.e. starting about every 3rd day of the year) to understand how each potential spill might behave under different meteorological and oceanic conditions accounting for seasonal and daily variability across a representative year. All of this was then combined into a single Combined Probability Map to show the likelihood of a sensitive receptor being exposed to hydrocarbons from the Precinct development.

The modelling approach is based on using DHI's MIKE21 hydrodynamic model to simulate unsteady two dimensional flows which will move and disperse the spills. MIKE21 is an industry standard model that has been widely applied in a large number of studies worldwide. Further details of the MIKE21 model and a full description of the hydrodynamic setup, calibration and validation are provided in **Appendix G-3** and supporting technical appendices.

The Spill Analysis module of the MIKE21 modelling system was developed to predict the fate of hydrocarbon spills (see **Appendix G-3**). The module simulated the spreading and weathering of hydrocarbons in the aquatic environment under the influence of the hydrodynamic processes and associated physical and chemical dispersion processes such as advection/dispersion, evaporation, mechanical spreading, dissolution and emulsification. The processes were calculated based on the chemical and physical properties of the hydrocarbon constituents.

Figure 4-2 summarises the overall approach to modelling and the associated post processing of results to show the combined outcomes from a large number of runs for all modelled scenarios. Full details are outlined further in **Appendix G-3** (Section 3.4).

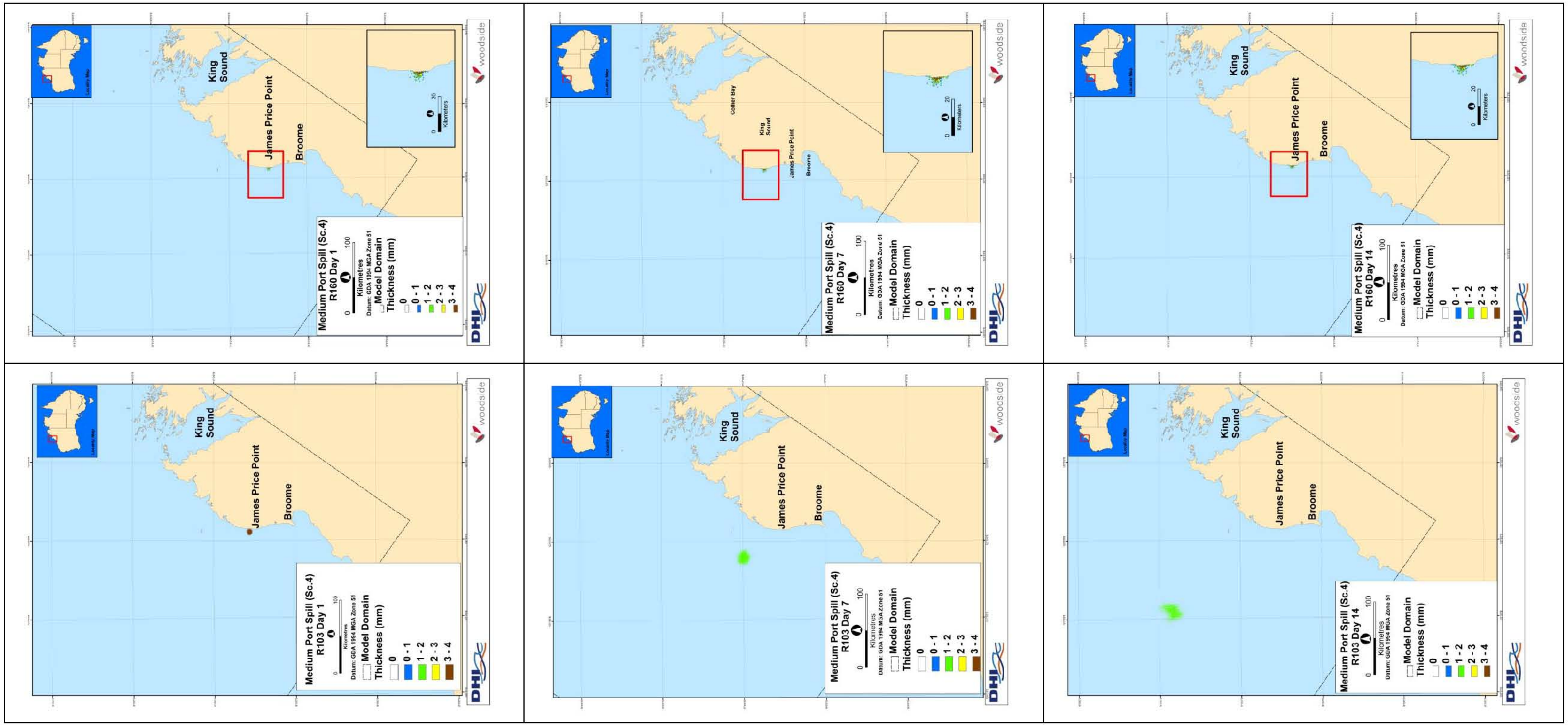


- **Figure 4-2 Conceptual Diagram of Modelling and Post Processing Approach for Hydrocarbon Spill Analysis.**

4.3.3. Key Findings

The results of the hydrocarbon spill modelling indicate that spills would be predominantly pushed offshore by seasonal south-easterly winds or towards the adjacent coastline by prevailing onshore winds (i.e. prevailing winds are likely to minimise the movement of a spill along the coastline).

Representative figures showing the typical fate, including thickness, direction and timescale of a medium sized (270m^3) hydrocarbon spill in the proposed port area are provided in **Figure 4-3**. The medium spill was selected as this is the largest instantaneous spill with a probability greater than 1 in every 10,000 years (the likelihood of this occurring is 1 in every 5,000 years). For example, the probability of a large instantaneous condensate port spill is 1 in every 17,000 years, and a bunker fuel risk is in the order of 1 in every 12,000 years. These individual model runs support the key findings where prevailing winds are the predominant force in driving the direction of a spill. The effect of strong south-easterly winds and the contrasting calm periods followed by onshore winds prevent the modelled spill from impacting a large area of coastline.



- **Figure 4-3 Time Series for First 14 Days of Model Outputs for the Medium Volume Port Spill. Run 103 Shows the Effect of Strong South-easterly Winds Compared to Run 160 which Shows the Effect of Calmer Periods followed by an Onshore Wind.**

Note Figures should be read from left (Day 1) to right (Day 14).

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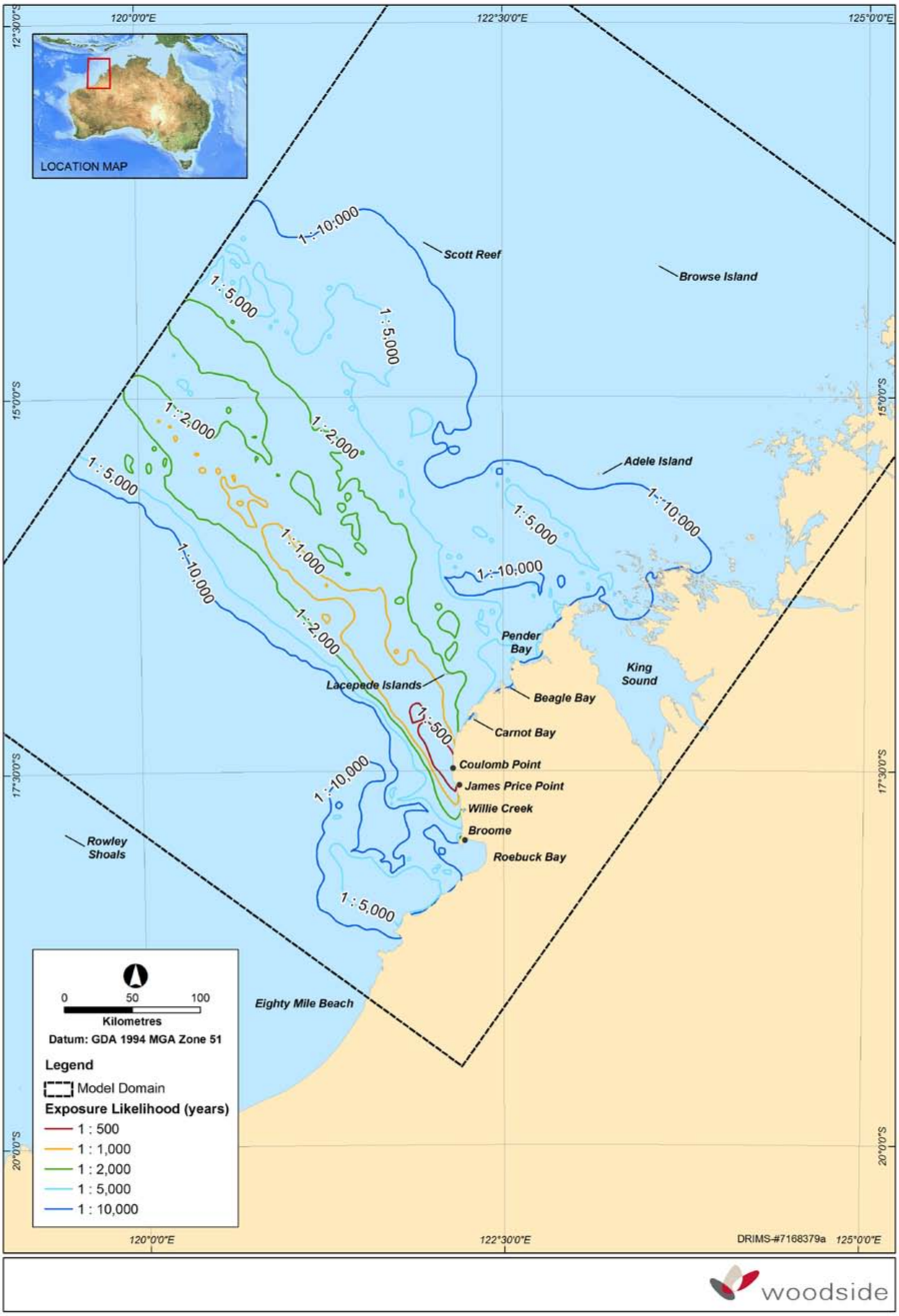
The likelihood of a location being impacted by hydrocarbons, from any of the modelled hydrocarbon spill scenarios under a broad range of meteorological conditions, is shown in **Figure 4-4**. Modelling demonstrates that the likelihood of a spill impacting the shoreline beyond 15km from James Price Point is very low, in the order of 1 in every 1,000 years. Other regionally significant receptors, such as the Lacepede Islands, Roebuck Bay, Cable Beach and 80 Mile Beach, are at a very low risk from exposure to spills. Modelling indicates these areas have an approximate likelihood of exposure to hydrocarbons ranging from 1 in every 2,000 years (Lacepede Islands) to less than 1 in every 10,000 years (Roebuck Bay).

How to Read the Modelled Probability Plots (refer to contour plots on Figure 4-4)

The modelled plots show the probability of exposure to hypothetical hydrocarbon spills and do not represent actual spill sizes nor do they represent or depict the area over which spilled hydrocarbon from any one event would spread. This would be far smaller in area than the areas over which probability contours are shown in the plots. Rather, the plots indicate if the spill occurred on any given day in the year, the chance it would get to that given location.

For example, if you stood at the Lacepede Islands for 2,000 years, probabilistically you would see a single spill.

It should be noted that the probability of a spill being less than 1:10,000 has been set as an upper threshold. This was seen as a reasonably conservative limit in that this is the period since the end of the last ice age.



- **Figure 4-4 Combined Exposure Likelihood of Hydrocarbon for all Identified Spill Events.**

Note: It should be noted that this figure does not predict the pathway or fate of a particular hydrocarbon spill event, but the probability of exposure from any operational hydrocarbon spill. The figure shows the combined likelihood of hydrocarbons reaching a location from the combination of all identified hydrocarbon spill events.

Table 4-2 identifies some key sensitive receptors showing:

- the likelihood of these locations being exposed to hydrocarbons;
- the minimum time expected for hydrocarbons to reach this location; and
- the maximum thickness of oil that would ever be expected to reach the location.

It should be noted that the minimum time and maximum thickness are independent. That is, where a modelled hydrocarbon spill reaches the location in the minimum time, it would not necessarily be at the maximum thickness or ever reach that maximum thickness for that modelled spill that reached the location in the fastest time.

- **Table 4-2 Analysis of Potential Hydrocarbon Spills on Sensitive Receptors.**

Location	Combined Probability	Maximum Concentration of Hydrocarbon [g/m^2]	Minimum time to exposure [Days]
Lacepede Islands	1 in every 2,000 years	60	7
Browse Island	-	-	-
Adele Island	-	-	-
Scott Reef	-	-	-
Pender Bay	1 in every 10,000 years	39	29
Carnot Bay	1 in every 10,000 years	69	8
Roebuck Bay	1 in every 10,000 years	68	10
Willie Creek	1 in every 3,000 years	119	5
Cable Beach	1 in every 10,000 years	82	6
Eighty Mile Beach	-	-	-
Coulomb Point	1 in every 10,000 years	83	9
Beagle Bay	1 in every 10,000 years	43	19
Rowley Shoals	-	-	-

Note: - Below modelling threshold

Other key findings from the hydrocarbon spill modelling demonstrate that:

- A relatively small percentage of the total number of spills simulated (approximately less than 10%) are retained or forced back onto the coastline under south-west wind conditions. Of these events, there is a very low number of spills that move offshore and are then returned to the coast further to the north or south.
- Spills can travel an estimated 20km or more per day, and the offshore trajectory (as shown on **Figure 4-4**) is a reflection of prevailing wind and tidal patterns. Spills that are subject to less common winds from other directions will move similar distances, which is reflected in the small number of spills that travelled south of Roebuck Bay.
- Water movement in the James Price Point coastal area is strongly influenced by tides, particularly during spring tides with strong ebb and flood flows when spills could move quickly within the scale of a nominal tidal ellipse of between 2 and 10km. This would require rapid response times to address spills of all sizes and effective combat measures to be taken immediately after a significant spill occurring.

4.4. Assessment against SAR Impact Conclusions and Outcomes

4.4.1. Predicted Impacts

4.4.1.1. Environmental Factors

As described in **Part 3**, **Section 2.3.4** (Marine Water Quality) of the Strategic Assessment Report, there is a potential for non-routine discharges of hydrocarbons to the marine environment during the processing, storage and handling of hydrocarbons. However, with modern design and preventative measures (discussed further in **Section 4.4.2.1**) the likelihood of a major spill or leak occurring is very low. Nonetheless, the impact of such an event could be significant without appropriate mitigation and contingency response.

The supplementary hydrocarbon spill modelling study focused on the fate of spilled hydrocarbons and the likelihood of impact from representative hydrocarbon spill scenarios. The findings of the study show that coastal impacts from hydrocarbon spills are likely to be limited to the James Price Point coastal area during calm periods and onshore winds, moving offshore with prevailing south-easterly winds. The likelihood of any hydrocarbon spill impacting on regionally significant environmental receptors is low, ranging from 1 in every 2,000 years for the Lacepede Islands to less than 1 in every 10,000 years for Roebuck Bay.

Without early intervention, strong tidal movements could result in the rapid spread of a hydrocarbon spill within the range of a nominal tidal ellipse. A range of management measures have been proposed to ensure the response times are minimised and effective spill combat measures are employed in the event of a hydrocarbon spill, detailed further in **Section 4.4.2.2**.

A comprehensive site selection process (refer to **Part 2**, **Section 4**) led to the James Price Point area being ultimately selected as the site with least environmental constraints on the Dampier Peninsula and where environmental risks were likely to be manageable. This has minimised the likelihood of significant environmental impacts associated with non-routine spills should they occur as a result of BLNG Precinct activities, as key sensitive receptors are distant and have been avoided.

4.4.1.2. Social Factors

The potential impacts of a hydrocarbon spill are a significant concern for local community members but particularly for those who use the marine environment for commercial, recreational or customary purposes. These concerns were heightened by the Montara accident in August 2009 off the north-west coast of Australia.

A range of organisations use the marine environment for their livelihoods and could be impacted by a significant hydrocarbon spill. These include tourism operators, customary fishers, commercial fishers and aquaculture businesses, as described in previous sections of this report. Government regulation and strict industry safety standards, procedures for product handling/storage and spill response planning will mitigate the likelihood and extent of a spill. Notwithstanding these measures, the Strategic Assessment recognises the potential for social impacts on a range of factors, as summarised below and detailed in **Part 5**.

Customary Fishing (**Part 5**, **Section 3.8**) provides an important food source for the people of the Dampier Peninsula. It represents a significant part of their diet and also plays a key part in the maintenance of Aboriginal culture. Changes to the local marine environment are likely to impact on the cultural fishing undertaken in the area. As discussed in **Part 5**, **Section 4.4** (Visual Amenity, Light and Landscape Character), non-routine discharges (i.e. spills and leaks), although highly unlikely, can result in a significant effect on water quality, which can have flow-on impacts on visual amenity and changes to the seascape and landscape character of coastal areas. **Part 5**, **Section 4.5** (Commercial Fishing), recognises that a non-routine marine discharge could result in impacts to marine biota. **Part 5**, **Section 4.6** (Aquaculture and Pearling) recognises that a significant spill could have physical effects on pearl oysters: including coating and/or smothering leading in certain cases to contamination and mortality; and chemical and biological effects (toxicity and bioavailability). **Part 5**, **Section 4.7** (Tourism) states that marine discharges may impact on the sense of place and local amenity of the area, and in turn affect tourism values as a result of a major discharge or spill into the marine environment. **Part 5**, **Section 4.8** (Sports, Recreation (including recreational fishing) and Land Use) highlights that the marine areas around James Price Point are popular recreation areas, particularly for Broome residents. Marine discharges may impact on the sense of place and local amenity of the area, and in turn affect recreational use as a result of a major discharge or spill into the marine environment.

4.4.2. Mitigation and Management

The environmental outcomes predicted by the supplementary hydrocarbon spill modelling are considered consistent with those presented within **Part 3**, **Section 2.3** (Marine Water Quality) and repeated for the relevant environmental factors (**Part 3**, **Section 2.2** (Marine Sediments)**, Part 3**, **Section 2.4** (Benthos) and **Part 3**, **Section 2.8** (Marine Ecosystem Integrity)). Specifically, the area impacted by a hydrocarbon spill is likely to be determined by prevailing winds and tidal forces. The social outcomes predicted from the hydrocarbon spill modelling study are also consistent with those originally presented within the Strategic Assessment Report.

The measures outlined within the Strategic Assessment Report are also considered to be appropriate in mitigating and managing the potential impacts to an acceptable level. In particular, Government regulation and strict industry safety standards, procedures for product handling/storage and spill response planning (described in **Part 3**, **Section 2.3.5**) will mitigate the likelihood and extent of a spill. These mitigation measures include the preparation and implementation of a Hydrocarbon and Chemical Spill Contingency Plan, to the satisfaction of the Western Australian Minister for Environment. See **Part 3**, **Section 2.3** (Marine Water Quality).

The Broome Port Authority (**BPA**) has existing responsibility for hydrocarbon spill preparedness and response for areas in its jurisdiction. With particular regard to oil spill response capabilities of the Broome Port Authority, the following points reinforce this capability and responsibility through the appropriate provision of resources, equipment and training:

- The Port authority is currently responsible for the immediate response and management of tier 2 incidents in the region.
- BPA has a stockpile of response equipment and dispersant, sufficient for a first strike capability. This would be supplemented by the Dampier stockpile in the event of a large spill.
- BPA currently has two senior staff trained as oil spill operations managers, and a dozen trained as OSR team members. Two are trained as team leaders.
- Core Oil Spill Response (**OSR**) personnel have attended the last two major state exercises and have fulfilled operations, administration, media, equipment, beach clearance, and general logistics duties.
- Regular training programs are undertaken in conjunction with Department of Transport oil spill specialists.
- In line with the BLNG Precinct Environmental Management Plan (**BPEMP**) already committed in the SAR, equipment would be located at the Precinct to hasten response to any oil spill during the early construction phases.

4.4.2.1. Preventative Measures

Maintenance and integrity of LNG facilities and associated infrastructure is paramount to the longevity and sustainability of the Australian LNG industry. As such, stringent regulatory requirements and industry standards are applied to LNG proponents to ensure their activities are undertaken to minimise the likelihood of hydrocarbon spills to as low as reasonably practicable.

Preventative measures for loss of hydrocarbon containment are introduced at the earliest stages of facility design and engineering to ensure facilities are built to accommodate a range of both environmental and anthropogenic events that may be encountered such as cyclonic activity; lightning strikes; tsunamis and ocean level rise; vessel anchoring in shallow waters and trawling vessels. Design measures to prevent the release of hydrocarbons to the environment as a result of the failure of pipelines or vessels include secondary containment (e.g. bunding) of hydrocarbon storage areas, rock armouring of pipelines and strict material specifications to ensure the technical integrity of a facility is maintained.

In addition to the regulatory requirements and industry standards driving safe design and engineering of LNG facilities, procedural and operational measures are implemented to ensure facilities are regularly maintained and operated to prevent the unplanned release of hydrocarbons. Operational procedures are implemented for activities such as ship loading, fuel transfers and waste handling to ensure operations are conducted safely, thereby minimising the risk of an unplanned hydrocarbon spill. Other preventative measures include regular maintenance and inspections of pipelines, vessels and other equipment to ensure technical and structural integrity is maintained.

Western Australian Government agencies such as the Department of Environment and Conservation and the Department of Mines and Petroleum conduct regular inspections and audits of LNG facilities to ensure statutory requirements are met by the operator and to identify improvements that can be made to achieve a better environmental

and safety outcome. Whilst the scope of these inspections differs according to the legislative framework under which these agencies work, the outcome is to ensure LNG facilities are designed, operated and maintained appropriately to minimise risks to the environment and to improve the safety of personnel.

4.4.2.2. Oil Spill Contingency Planning

The State Emergency Management Plan for Marine Oil Pollution (WestPlan Marine Oil Pollution (**WestPlan-MOP**)) has been developed by the Western Australian Department of Transport under the *Emergency Management Act* 2005 (**EM Act**) to detail the management arrangements and response to a marine oil pollution incident in order to minimise the effects of oil pollution incidents occurring in State waters. The WestPlan-MOP also integrates with a number of related emergency plans such as the National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances and the State Emergency Management Plan for Hazardous Materials Emergencies (**WestPlan-HAZMAT**) (which deals with spills of other noxious substances). A number of sub-plans have also been developed to guide the coordinated response to a significant hydrocarbon spill (for example, the WA Oiled Wildlife Response Plan).

Consistent with the WestPlan-MOP, the following management arrangements are proposed in the SAR to ensure that, in the unlikely event of a major hydrocarbon spill, appropriate response measures are deployed in a timely and effective manner to minimise the effect of such a spill:

- Broome Port Authority will be designated as the statutory port authority for the BLNG and will therefore be responsible for preparing an Emergency Response Plan, including oil spill contingency procedures and coordination of proponents in the event of emergency response procedures. (Refer additional detail in **Table 4-3** below).
- Additional hydrocarbon spill modelling will be required to be undertaken by future proponents during the derived proposal process which will assist development of oil spill contingency plans.
- Future proponents of derived proposals will be required to prepare and implement a Hydrocarbon and Chemical Spill Contingency Plan, which addresses the following:
    - effective and timely management of spills;
    - roles and responsibilities of response personnel;
    - procedures for incident response;
    - objectives, targets and associated monitoring; and
    - alignment and compliance with the State Government Precinct Emergency Response Plan.
- All vessels entering the BLNG Precinct will be required to have in place a Ship-Board Oil Pollution Emergency Plan.

In summary, **Table 4-3** identifies the updated commitment in this SAR Supplement, to reflect similar structure to what was presented in **Part 3, Section 2.3**, to be implemented by the State Government to ensure appropriate preparedness and response capability in the unlikely event of a spill.

- **Table 4-3 State Government Measures for the Management of Impacts on Water Quality (as relevant to hydrocarbon spill management).**

State Government Measure	Responsibility	Timing
Existing commitment (presented in Part 3, Section 2.3):		
Establish the Broome Port Authority as the statutory Port Authority for the BLNG Precinct and an associated port area, which would have functions including regulation of: • marine construction within the port area; • long term dredging and spoil disposal program and management strategy to service the port area; • vessel navigation, operations and movements within the port area; • establishment and management of exclusion zones; and • environmental and risk management within the port area.	Department of Transport (DoT)	On approval of BLNG Precinct
The Port Authority will prepare a BLNG Precinct Environmental Management Plan for the port area in consultation with DEC and other relevant agencies, which addresses the following: • collation of adequate environmental baseline data for marine mammals, turtles, water quality and benthic habitat health within the port generally; • an ecological and water quality monitoring program within the port boundaries and appropriate reference areas; • identification of key environmental values and development of water quality objectives and criteria for waters within the Port; • an audit of operational marine facilities and construction activities to assess compliance of proponents against the performance requirements of the BPEMP; • an Emergency Response Plan including oil spill contingency procedures and coordination of proponents in the event of emergency response procedures; • preparation and enforcement of vessel operating requirements including invasive marine species management; • stakeholder consultation; and • reporting and review mechanisms.	Broome Port Authority	Prior to approval of marine related derived proposals
Updated commitment (reflecting outcome of SAR Supplement):		
In addition to the existing commitments described above, the commitment to prepare an Environmental Management Plan will also address: • resourcing and maintenance of hydrocarbon spill response equipment with the capacity to effectively respond to a tier two (10 -1000t) event; and • training of personnel to effectively respond to a hydrocarbon spill within the port boundaries.	Broome Port Authority	Prior to approval of marine related derived proposals

4.5. Conclusion

Although the likelihood of a significant hydrocarbon spill from activities at the proposed BLNG Precinct is very low, the potential environmental impacts are significant if effective response measures are not implemented. Therefore, hydrocarbon spill events pose a significant concern for local community members, particularly for those that use the marine environment for commercial, recreational or customary purposes.

Hydrocarbon spill modelling has been undertaken to support the SAR and to identify the likelihood of an oil spill impacting on key sensitive environmental and social receptors, from a number of oil spill scenarios. The modelling demonstrates that the extent of a hydrocarbon spill near the proposed BLNG Precinct is predominantly driven by prevailing winds and tidal forces, which act to minimise the movement of a spill along the Dampier Peninsula, thereby minimising coastline impacts in the Kimberley region.

The comprehensive site selection process, whereby James Price Point was ultimately selected as the site with least environmental constraints on the Dampier Peninsula, has minimised potential impacts associated with non-routine discharges, should they occur, as regionally significant environmental and social receptors are distant and highly unlikely to be impacted. However, a comprehensive planning and management process is proposed for the BLNG Precinct to ensure that an effective and coordinated response is implemented should a significant hydrocarbon spill occur. Implementation of the proposed management measures, including the establishment of the Broome Port Authority and development of Hydrocarbon and Chemical Spill Contingency Plans to inform the response to a significant spill, will minimise the environmental and social impacts from such an event.

The application of 'Best Practice', as defined in the SAR, would ensure that LNG facilities are designed, operated and maintained appropriately to avoid or minimise risks to the environment and to improve the safety of personnel.

5. Supplementary Coastal Processes Modelling

5.1. Introduction

The development of the BLNG Precinct will affect coastal processes and sediment transport due to changes induced by the proposed port, channel and marine infrastructure (i.e. a breakwater). The alteration of these coastal processes may result in an impact on marine ecological communities.

The significance of these impacts have been assessed for coastal processes in **Part 3** (Environmental Assessment – Marine Impacts), and social factors are considered in **Part 5** (Social Assessment). The impact assessment in the SAR was supported by site assessments and modelling of existing coastal processes in the James Price Point coastal area.

The following section provides a summary of the results of further coastal processes modelling undertaken, specifically to assess whether the predicted impacts, and corresponding management measures, are acceptable and manageable in the context of the BLNG Strategic Assessment.

5.2. Relevant Factors

5.2.1. Environmental Factors

The study conclusions regarding the supplementary coastal processes modelling are primarily relevant to the following environmental factors:

- Tidal Regimes, Wave Climate, Currents and Hydrodynamics (**Part 3**, **Section 2.1**); and
- Marine Ecosystem Integrity (**Part 3**, **Section 2.8**).

5.2.2. Social Factors

The study conclusions regarding the supplementary coastal processes modelling are primarily relevant to the following social factors:

- Customary Fishing (**Part 5**, **Section 3.8**);
- Visual Amenity (**Part 5**, **Section 4.4**);
- Commercial Fishing (**Part 5**, **Section 4.5**);
- Aquaculture and Pearling (**Part 5**, **Section 4.6**);
- Tourism (**Part 5**, **Section 4.7**); and
- Sports, Recreation (including recreational fishing) and Land Use (**Part 5**, **Section 4.8**).

5.3. Study Overview

5.3.1. Objectives

The coastal processes study was undertaken to meet the following key overall objectives:

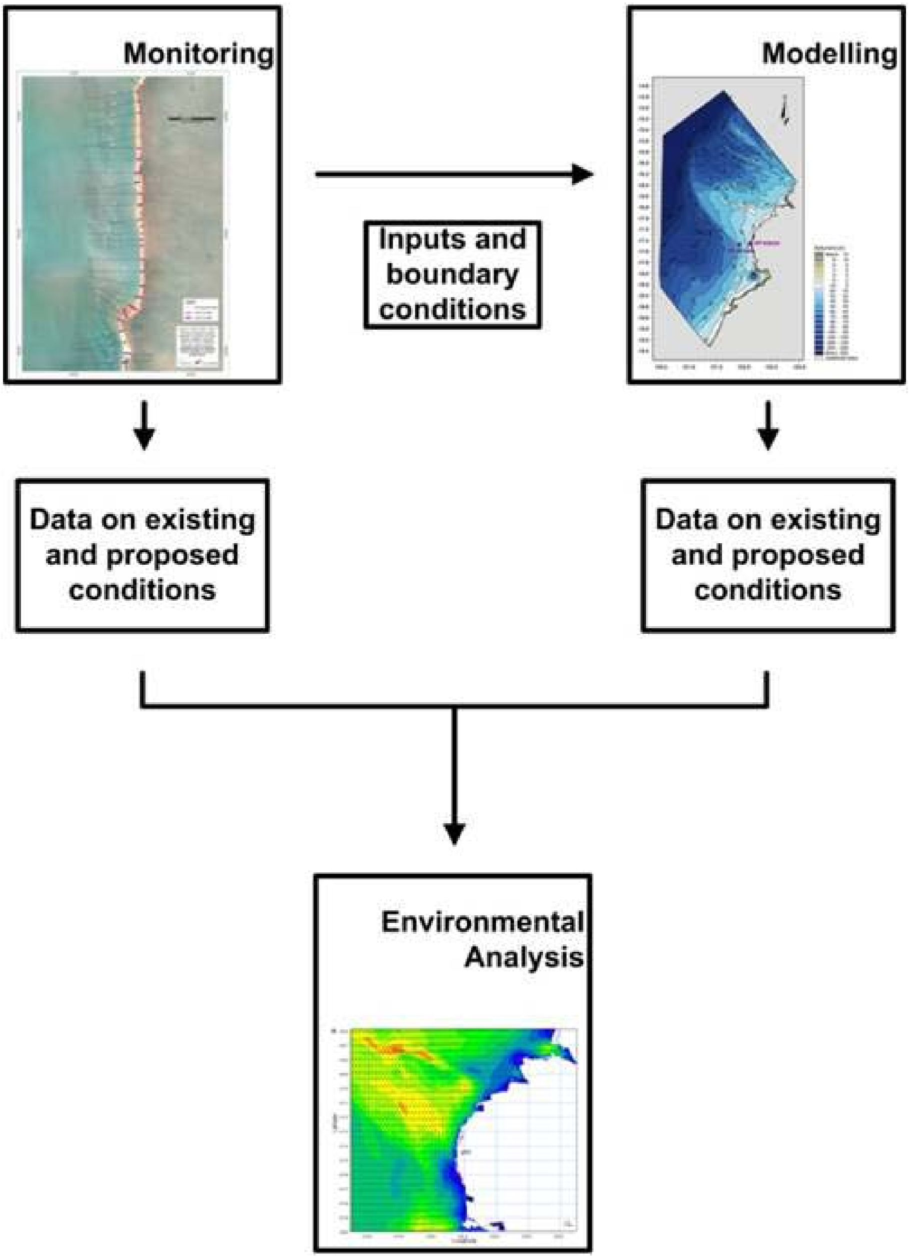
- to describe the geomorphological characteristics of the site;
- to identify the existing sediment transport pathways; and
- to assess the likely impacts to sediment transport patterns and morphology as a result of the development of the Browse LNG Precinct Port.

5.3.2. Methodology Overview

The coastal processes study was undertaken by DHI Water and Environment (DHI, 2011c; **Appendix G-4**) to further examine the existing geomorphological and sediment transport characteristics of the coastal zone. This study has informed the Strategic Assessment on the potential for the development of the port infrastructure to alter the coastal processes and sediment transport pathways and therefore modify the form of the coast. A summary overview of the approach is presented below, with further details included in **Appendix G-4**.

The assessment methodology for this study is based on the main components outlined in **Figure 5-1** and described as follows:

1) Development of an understanding of the site through a review of available data, geomorphological assessment and numerical modelling.
2) Estimate the existing littoral sediment transport regime using numerical modelling over a 20 year time period.
3) Assess the impacts from the project on the local sediment transport pathways using two-dimensional, numerical transport modelling under ambient (non-cyclonic) and selected cyclonic conditions.
4) Estimate the changes to waves, currents and sediment transport pathways by comparing the modelling results for the existing condition with modelling results following project construction.
5) Determine the extent and magnitude of likely morphological impacts following a review of the modelled changes in wave, current and sediment transport patterns caused by the project.
6) Assess the impact of the changes to the sediment transport regime and coastal morphology in the context of the existing coastal environment.



- **Figure 5-1 Conceptual Diagram of Assessment Approach for Coastal Processes Modelling.**

5.3.3. Key Findings

5.3.3.1. Geomorphology

Key findings of the existing coastal processes and geomorphology (Oceanica, 2010; attachment to **Appendix G-4**) are summarised below:

- The volume of sediment in the active coastal zone is relatively limited.
- The coastal morphology is strongly controlled by the underlying geologic structure (e.g. intertidal rock platforms, headlands, rocky outcrops).
- The dominant force for sediment transport and changes in coastal morphology is likely to be cyclones.
- Pathways for the contribution of sediment in the active coastal zone include: marine erosion of the Pindan soils; onshore transport of marine sands from further offshore; washouts during severe runoff events; biogenic production (generation of sedimentary material by marine organisms, e.g. shell formation); marine erosion of dunes; and wind transport from land.

The main geomorphologic features observed in the James Price Point area are presented in **Table 5-1**.

Selected aerial photography between 1949 and 2007 was used to examine the shoreline stability over this 58 year period (Oceanica, 2010). Representative figures are included as **Figure 5-2** and **Figure 5-3**, with full details provided in **Appendix G-4** and supporting technical appendices. The historical analysis shows the long-term stability of the backshore in the James Price Point area. The minimal changes in the position of the backshore over the analysis period demonstrates the relative stability of the cliffs and the dunes landward of the initial foredune.

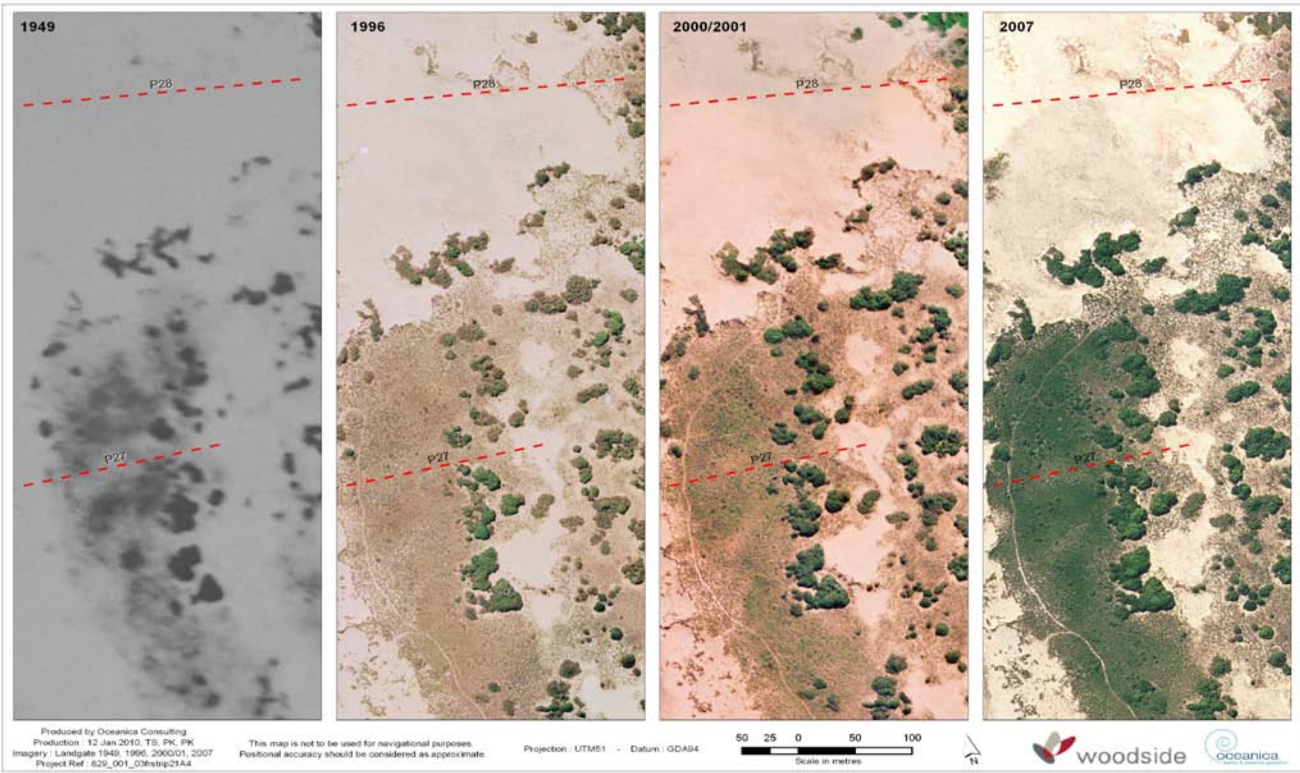
Representative photographs of selected geomorphological features are provided in **Figure 5-4** and **Figure 5-5**.

The potential morphological impacts predicted by the coastal processes modelling, as a result of the development of the BLNG Precinct nearshore infrastructure, are expected to be:

- Shoreline accretion immediately adjacent to the northern and southern breakwaters.
- Increased erosion potential focussed in a zone approximately 2–3km north and south of the harbour.
- The increased erosion potential may lead to a localised reduction in sediment volume on the beach and an increased potential for backshore erosion in these regions. To the north (see **Figure 5-4**) the backshore is composed of pindan soils and are somewhat resistant to erosion; whereas to the south (see **Figure 5-5**) the backshore is underlain by rocky cliffs and the erosion of these cliffs is likely to be minimal.
- Without mitigation, the zone of increased erosion potential would gradually migrate southward.

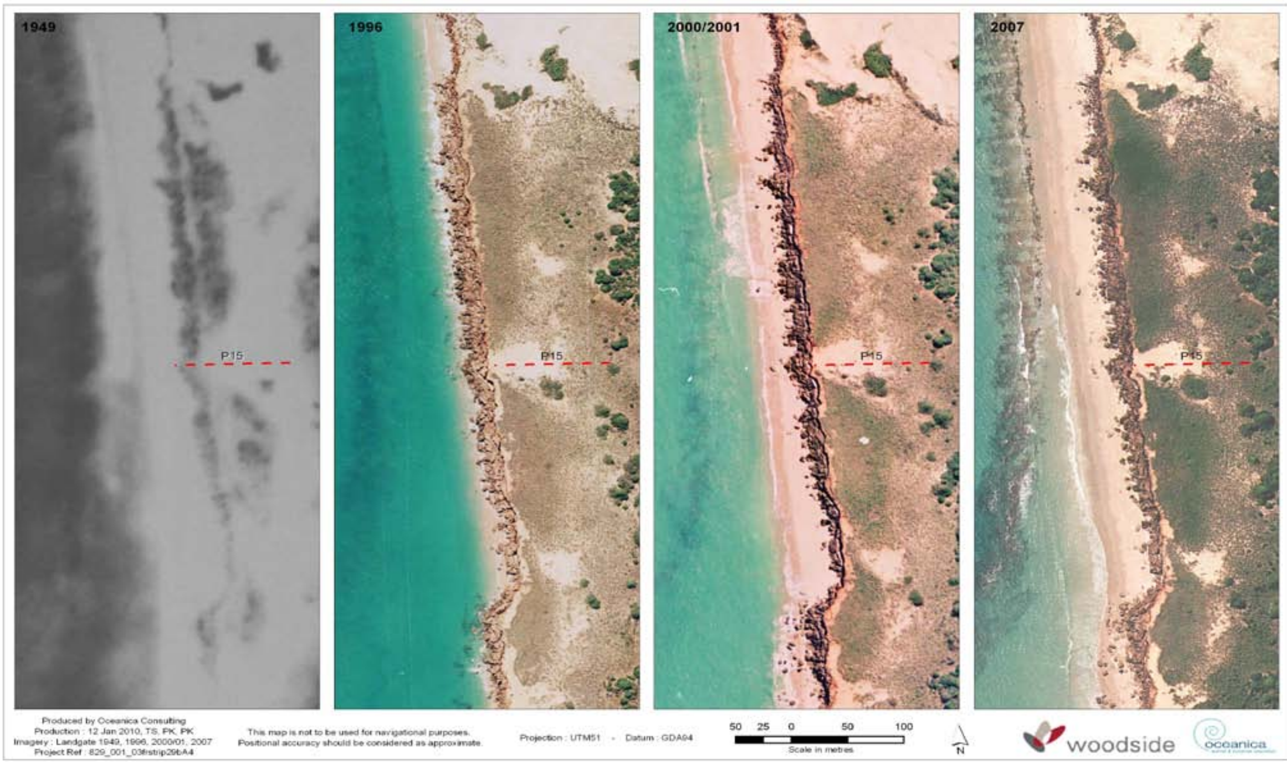
- **Table 5-1 Geomorphologic Features of the James Price Point Coastal Area.**

Geo-morphologic feature	Description	Example photographs	
A) Cretaceous Broome sandstone	• Variable in consolidation and bedding, with conglomerates and iron-staining • Outcropping on beach • Low-tidal platforms • Form headlands which control the coastal morphology		
B) Pleistocene Pindans	• Seaward edge of pindans exhibits cliffing • Varied level of reworking • High quartz, with iron-staining (red colour) and high silt and clay content		
C) Pleistocene Coastal limestone	• Carbonate sediments with variable cementation in response to groundwater (south of JPP) • Outcrops as beachrock • Karst features on some terrace areas south of JPP • Also located offshore		
D) Holocene sands	• Form dunes, beach and veneer offshore • In areas has been weakly cemented (in the dunes)		



- **Figure 5-2 Representative Figure of Historical Aerial Photography of Shoreline Change near James Price Point (1949 – 2007, in Vicinity of Proposed Central Shore Crossing for Port Facilities).**

Note: Refer **Appendix G-4** for full analysis and complete photographic dataset.



- **Figure 5-3 Representative Figure of Historical Aerial Photography of Shoreline Change Immediately north of James Price Point (1949 – 2007).**

Note: Refer **Appendix G-4** for full analysis and complete photographic dataset.

- **Figure 5-4 Photography of Pindan Soils which forms the Backshore in the Area Approximately 2–3km North of the Proposed Port Facility.**

- **Figure 5-5 Photography of Rocky Cliff which forms the Backshore in the Area Approximately 2–3km South of the Proposed Port facility (Left: 1.5km South and Right: 3.5km South).**

5.3.3.2. Sediment Transport

The modelled sediment transport rates assume an unlimited supply of sediment, and consequently represent maximum potential transport rates. Due to the prevalence of hard substrate throughout the inshore area, sediment availability is significantly constrained and the *actual* sediment transport rates will therefore be much less than the modelled *potential* rates.

Modelling of the *potential* sediment transport rates showed:

- Sediment transport was generally directed northward throughout most of the year; however, during the cyclone season (December-March) there are often large southerly sediment transport events.
- Net sediment transport was generally in the order of 20,000m^3/year northward during the ambient conditions which prevail during most of the year.
- Under cyclonic conditions the volume and direction of sediment transport can be highly variable. However, due to the clockwise rotation of cyclones in the Southern Hemisphere, the cyclones typically generate waves from north-westerly directions at the site, which leads to predominantly southerly directed sediment transport. Modelling of cyclonic events showed them to be highly variable, resulting in a variation over the 20 years in the net transport from 10,000m^3 northward to 60,000m^3 southward and an average of 40,000m^3 southward.

Due to the strong influence of tropical cyclones on the wave climate in the area, significant inter-annual (between years) and intra-annual (within year) variations in the transport rates is observed (**Figure 5-6**). The figure shows a progressive net northward sediment transport during ambient conditions (upward trends on graph) interrupted by cyclones which drive rapid southward pulses of sediment transport (steep drops on graph).

- **Figure 5-6 Time Series over 20 Years of Accumulated Net Littoral Sediment Transport Rates.**

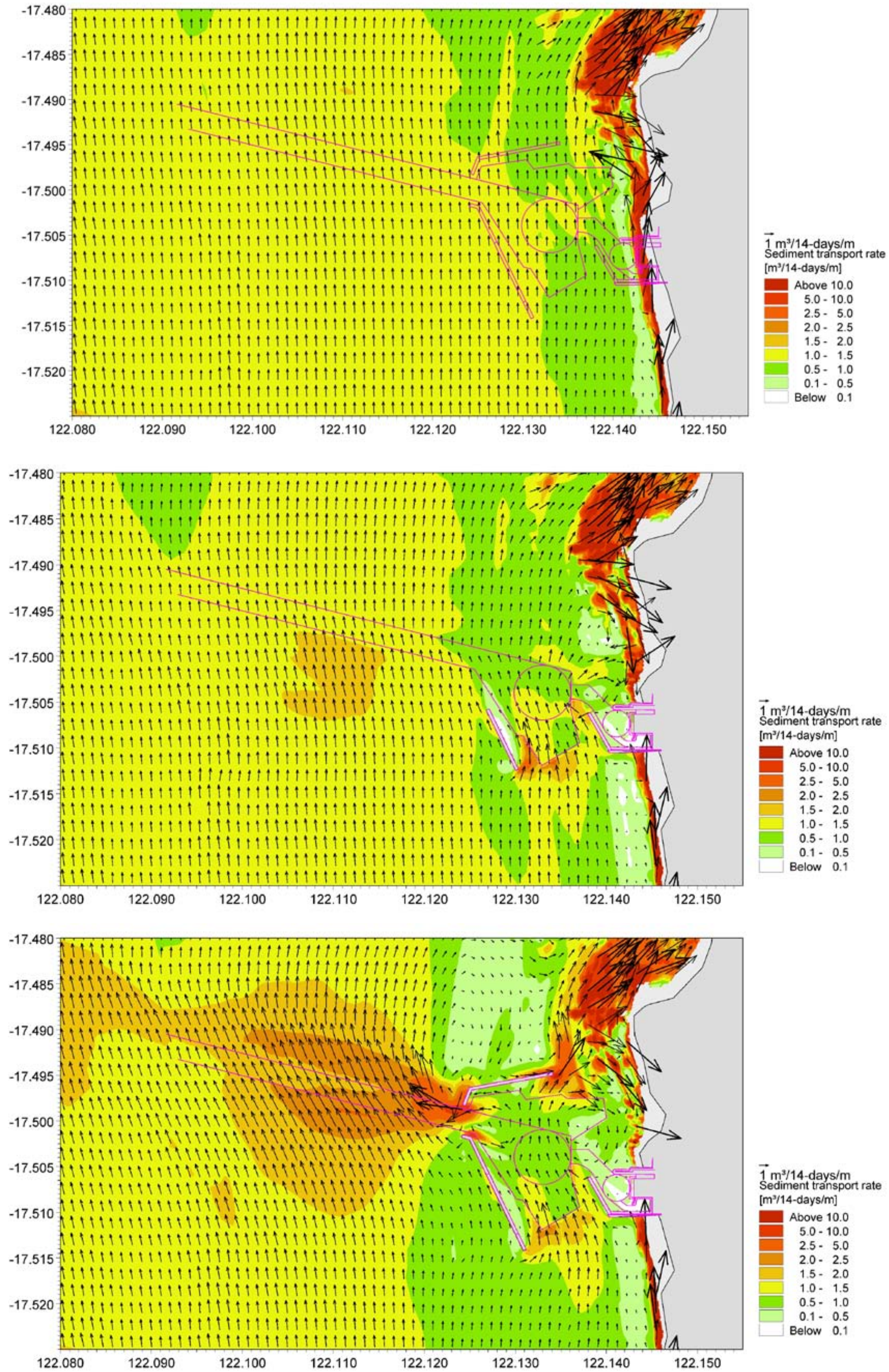
Note: Negative transport rates corresponds to southerly directed transport while positive rates correspond to northerly directed transport. Refer **Appendix G-4** (Section 6.2) for further details.

Modelling of the cumulative sediment transport over 14 days of ambient conditions (**Figure 5-7**) with further analysis provided in **Appendix G-4**) indicates the importance of wave driven sediment movement in the surf zone close to the coast. The modelling also shows that the port infrastructure will block the net northward littoral transport during these ambient conditions. Most of the northward littoral sediment transport will accumulate against the southern breakwater and only a minor component will bypass the harbour to be trapped in the berth pocket and channel. An eddy structure to the north of the facility reverses the transport direction and causes a slight southward transport in this location and will lead to an accumulation of material against the northern breakwater and localised infill of the channel. The relative increase in depth in the approach channel is limited, consequently the effects on sediment transport will also be limited and largely confined to trapping of the coarser sediments in the channel.

In summary, blocking and trapping the littoral sediment transport due to presence of the Browse LNG Precinct port development is expected to have the following effects:

- Sediment will accumulate against the southern side of the south breakwater and the northern side of the north breakwater.
- Under ambient (non-cyclonic) conditions, there will be a deficit in potential northerly sediment transport in the order of 20,000m^3/year, which may lead to erosion in an area to the north of the port development.
- Under cyclonic conditions there will be a net deficit in potential southerly sediment transport of sediment to the south of the port development (highly variable but with a long-term average of 40,000m^3/year). This may lead erosion in an area from a few hundred metres south of the southern breakwater to about 2-3km towards the south.

Trapping of sediment in the main approach channel is not anticipated to have a significant impact on the morphology of the broader littoral zone. However, trapping of the littoral transport adjacent to the port development (e.g. berth pockets and turning basins) may act as an additional sink to the littoral zone and increase the erosion potential along the adjacent coastline. Some sediment starvation of local beaches (extending to James Price Point in the north and approximately 2-3km on either side of the project) is expected to take place in the short to medium term. However, the coastline is relatively erosion-resistant and erosion of the backshore is predominantly caused by cross-shore processes under severe cyclones rather than alongshore gradients in littoral transport. These processes will change very little along the coastlines outside the immediate area of sheltering by the port development.

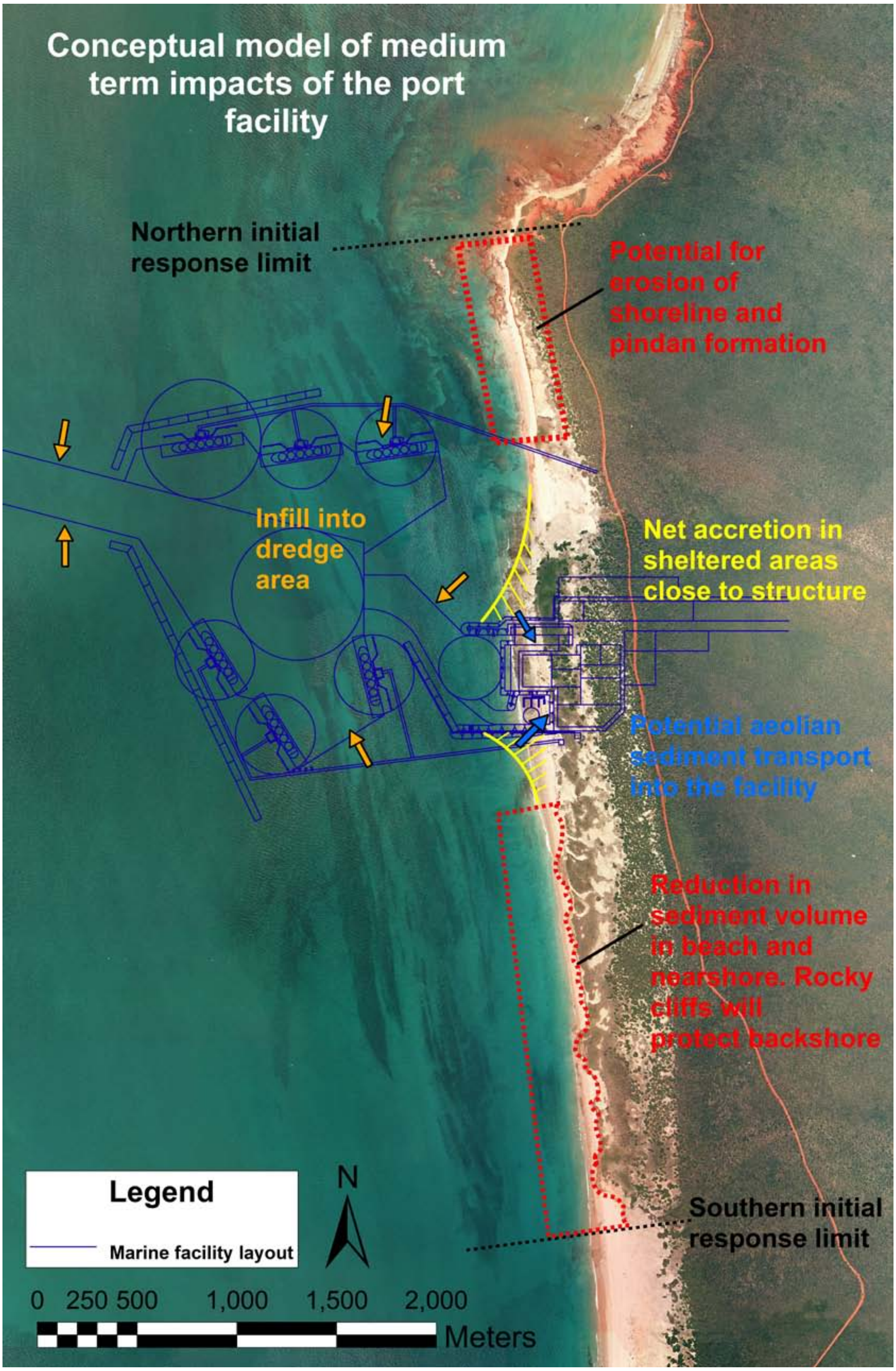


- **Figure 5-7 Accumulative Sediment Transport over 14 Days in October, for Existing Conditions (top), Phase 1 Scenario (middle, Representing Foundation Development) and Phase 2 Scenario (bottom, Representing Maximum Development Scenario for BLNG Precinct).**

To consolidate the results of the geomorphological assessment and coastal processes modelling, conceptual models for ambient and cyclonic conditions were derived. A conceptual model which summarises the predicted medium-term impacts as a result of the proposed port development is presented in **Figure 5-8**, with further details included in **Appendix G-4**.

Under ambient conditions, the actual littoral sediment transport moving northwards around James Price Point and Quondong Point is anticipated to be negligible. During cyclonic conditions, sediment transport can occur in deeper waters and bypass the rocky headlands at James Price Point and Quondong Point. As noted above, cyclonic sediment transport will typically be directed southwards. Coastal impacts to the north of James Price Point are therefore expected to be minimal, both in the short and long term.

The proposed port development will lead to a deficit in the existing sediment supply to the south, leading to sediment starvation of the beaches if it is not managed. If sediment bypassing is not managed, this area of sediment deficit, which will initially be limited to an area 2-3km south of the port, may gradually extend and affect areas further south. Within 2-3km south of the port the shoreline is backed by rocky cliffs which will limit backshore erosion and loss of vegetation or any areas of Aboriginal heritage. However, if the erosion was left unmanaged, the area of sediment deficit would extend to a small area which is not fronted by rocky cliffs. The backshore in this area (approximately 3km south of the port development) is characterised by a deflation basin and has limited vegetation cover which may contain Aboriginal heritage artefacts. Further south of this deflation zone the shoreline is typically backed by rocky cliffs which would be resistant to erosion. The mitigation measures presented at the conclusion of this section give due consideration to these key findings.



- **Figure 5-8 Conceptual Model for Medium Term Impacts on Coastal Processes Caused by Precinct Harbour.**

Note: Yellow hatched areas indicate expected accumulation areas, orange arrows pathways for infill of dredged areas, blue arrows potential aeolian transport from accumulation areas into facilities and red boxes the primary impact areas. Refer **Appendix G-4** for further details.

5.4. Assessment against SAR Impact Conclusions and Outcomes

5.4.1. Predicted Impacts

5.4.1.1. Environmental Factors

Preliminary modelling detailed in **Part 3**, **Section 2.1.3** (Tidal Regimes, Wave Climate and Currents), stated that under the ambient conditions, it is likely that sediment would be transported alongshore from the beaches in front of cliffs to the dune fields to the north in the vicinity of the proposed port development. The initial modelling demonstrated an intermittent pattern of erosion and deposition. A conservative estimate of the volume of ambient coastal sediment transport was determined to be between 10,000–20,000m^3/year. It was noted that cyclones can lead to both southerly and northerly directed transport, with a dominance of southerly directed transport due to the clockwise rotation of the cyclones. Over a 20 year simulation period (1989–2008), the maximum simulated net transport in the littoral zone over a single cyclone was in the order of 50,000m^3, with an average of 13,000m^3. Therefore, the predicted average annual net littoral transport (combined ambient and cyclonic transport) at the proposed port development location was predicted in the SAR to be in the order of 20,000 – 30,000m^3/year in a southerly direction. The supplementary modelling indicates that, on average, the northward sediment transport would be about 20,000m^3/year during ambient conditions, consistent with the estimates within the SAR. Modelling of cyclonic events showed them to be highly variable, resulting in a variation over the 20 years in the net transport from 10,000m^3 northward to 60,000m^3 southward and an average of 40,000m^3 southward.

It is anticipated that the proposed port development would act as a sediment sink and draw sediment from the adjacent coastlines. This effect would most likely be most evident to the south of the project. However, the coastline in this area is relatively well protected from erosion due to the extensive presence of rocky reefs and cliffs. This is supported by the historical analysis of aerial photography which show little movement in the backshore position between 1949 and 2007. The extensive presence of erosion resistant substrate and cliffs will significantly reduce the actual volumes of sediment transport from those modelled, as the modelling assumed an unlimited sediment supply. In any case, the main driver of large-scale shoreline erosion in this area is likely to be associated with the cross-shore exchange of sediments during cyclonic events rather than alongshore gradients in sediment supply. No significant change to existing processes is predicted to occur along the coastlines outside the immediate project area.

Nonetheless, it is reasonable to expect that some sediment starvation of beaches within approximately 2-3km on either side of the project is expected to take place in the short to medium term following port construction. The majority of this coast is underpinned by erosion resistant rocks and these areas may experience some reduction in beach sediments and an associated decrease in recreational value. If left unmanaged the additional erosion pressure initially experienced within the first few kilometres from the site may gradually extend southwards. The likely erosion potential is relatively small and Quondong Point is located approximately 7.5km further south; however, if left unmanaged there is the potential for beaches in the Quondong Point area to be impacted. This is discussed further in the following section.

The combined sedimentation of dredged areas has been estimated to be an annual average of 150,000 – 250,000m^3. The total estimated infill rates are considered well within the manageable range from a maintenance dredging point of view, with periodic maintenance dredging likely to be required. This is further discussed in **Appendix G-4**.

5.4.1.2. Social Factors

As discussed in **Part 5**, **Section 4.4** (Visual Amenity, Light and Landscape Character), the coastal landscape features are considered to be of high landscape value with overall high sensitivity. The development will cause changes to coastal processes which will impact on the seascape and landscape character of coastal areas. Taking into account the results of this supplementary coastal modelling study, there would be localised changes to some of the Landscape Character Units (**LCUs**) characterised in the SAR, in particular LCU1 (coastal areas) and LCU4 (nearshore areas) in the area immediately to the north and south of the Precinct. Outside this area, no significant changes in key values (intrinsic, recreational, topographical, etc) are anticipated assuming appropriate measures are implemented.

Part 5, **Section 4.7** (Tourism) states that the distinctive features of the coastal environment are important for onshore and marine tourism. Marine tourism includes local and regional luxury cruising as well as international cruise ships. Changes to these features have the potential to change the tourism character of the area. **Part 5**, **Section 4.8** (Sports, Recreation (including recreational fishing) and Land Use) states that there are potential indirect social impacts resulting from impacts to the physical environment. The area around James Price Point hosts some customary fishing,

recreational and commercial marine ventures. This area is characterised by steep hills and cliffs along some areas, so has less recreational shore-based fishing values than other areas to the north and south. Primary recreational fishing usage patterns in the locality are understood to be fishing reefs offshore the coast. Taking into account the results of this study, limited impacts on these values are predicted. However, active monitoring and management of potential impacts, in particular on more favourable beach areas to the south towards Quondong Point, have been recommended, as discussed further in the following section.

5.4.2. Mitigation and Management

The SAR proposes a range of mitigation and management measures outlined within **Part 3**, **Section 2.1** (Tidal Regimes, Wave Climate and Currents) and repeated for the relevant environmental factor (**Part 3**, **Section 2.8** (Marine Ecosystem Integrity)) to manage the potential impacts to an acceptable level.

To summarise, a range of management measures would be applied to mitigate potential impacts on coastal processes. The SAR outlined that such mitigation measures include:

- Establishment of the BPA as the statutory Port Authority for the BLNG Precinct and with regulatory functions for the associated port area.
- A requirement for proponents of derived proposals to prepare and implement a Port Facilities Construction Environmental Management Plan (**PFCEMP**), to the satisfaction of the Western Australian Minister for Environment.
- Conditions on derived proposals requiring that commercial proponents:
    - *demonstrate application of best practice measures to be implemented to minimise impacts on coastal processes from onshore and nearshore marine infrastructure, with design measures supported by detailed hydrodynamic modelling*; and
    - *develop and implement a Final Closure Plan, in consultation with key stakeholders, to be submitted to the Chief Executive Officer of Department of Environment and Conservation (**DEC**) at least five years prior to the planned date of closure.*

In particular, it is expected that the predicted impacts to the local coastal geomorphology can be successfully mitigated by the application of best practice management and design measures, consistent with the commitments outlined above. Local impacts can be managed by refining the infrastructure design. A regular coastal processes survey program will also be developed to monitor local influences from the port development and implement appropriate management actions if impacts are detected, in order to achieve acceptable outcomes.

Taking into account the results of the coastal processes study undertaken to inform the strategic assessment, the primary management response recommended by the Proponent is the development of a **Coastal Processes Management Plan**. An adaptive management approach based on regular monitoring is recommended to ensure that the sediment balance to the coastal zone immediately to the north and south of the port development is maintained and erosion impacts are minimised.

The Coastal Processes Management Plan will include consideration of appropriate triggers, timing and methods for sand management such that trapped material is returned to the coastal system or replaced by other material at a suitable location over an appropriate timeframe. The use of any dredged material for shoreline nourishment would depend on the physical characteristics and quality of this material. The Coastal Processes Management Plan will be developed in consultation with the Office of the Environmental Protection Authority and other key regulatory agencies. This will inform the development and implementation of the PFCEMP and ongoing management and monitoring commitments to be applied to future derived proposals.

The social outcomes determined from the Supplementary Coastal Processes Modelling study are consistent with those originally presented within the Strategic Assessment Report. The key mitigation and management measures are summarised above, and requires that proponents of derived proposals demonstrate application of best practice measures to be implemented to minimise the impacts on coastal processes from onshore and nearshore marine infrastructure.

In summary, the following table identifies the additional commitment in this SAR Supplement, in a similar format to that presented in **Part 3, Section 2.1**, to be implemented by proponents of derived proposals.

- **Table 5-2 Requirements to be Addressed via Development of a Management Plan to Support a Derived Proposal Potentially Affecting Tidal Regimes, Wave Climate, Currents and Hydrodynamics.**

Derived Proponent Requirements	Timing
Existing commitment (presented in Part 3, Section 2.1):	
Proponents of derived proposals shall prepare and implement a Port Facilities Construction Environmental Management Plan (**PFCEMP**), to the satisfaction of the Western Australian Minister for Environment, which addresses the following: • schedule of construction activities; • details of the construction methods to be used; • environmental training and inductions; • environmental monitoring, management, contingencies and reporting; • stakeholder consultation; and • consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.	Prior to commencement of associated construction activities
Additional commitment (reflecting outcome of SAR Supplement):	**Timing**
Proponents of derived proposals shall prepare and implement a **Coastal Processes Management Plan**, in consultation with OEPA and other key regulatory agencies, which addresses the following: • implementation of measures such that trapped material is returned to the coastal system or replaced by other material at a suitable location, so that the dynamic balance of sediment may be managed on a regional scale; • demonstration of best practice measures to be implemented to minimise impacts on coastal processes. Design measures to be demonstrated by detailed hydrodynamic modelling; • definition of scope of a regular coastal processes survey program to be implemented to monitor local influences from the BLNG marine infrastructure, and to inform appropriate management responses; • stakeholder consultation; and • consistency with requirements of Broome Port Authority and BLNG Precinct Environmental Management Framework.	Prior to commencement of associated construction activities

5.5. Conclusion

The following key conclusions are drawn, taking into account the results of the coastal processes study, to inform the Strategic Assessment:

- The coastline is exposed to a generally mild wave climate during ambient conditions, but with a high occurrence of cyclones that can generate severe wave climate and impacts to the coastline.
- Although the coastline is partly protected by erosion resistant reef and cliff the proposed port development will lead to a sediment deficit immediately adjacent to the facility. This zone of impact is likely to be limited to approximately 2-3km north and south of the development and is expected to occur over the short to medium term. Without mitigation, the increased erosion potential is predicted to gradually migrate southward.
- It is assumed that the port will interrupt all alongshore sediment transport. Hence, the magnitude of coastal impacts are largely determined by the sediment transport rates and less by the design of the port layout. The port layout will determine where the impacts occur (i.e. the size and location of the sheltered areas and the resulting sediment sink).
- It is expected that the predicted impacts to the local coastal geomorphology can be successfully mitigated by the application of best practice management and design measures, consistent with the commitments outlined in the SAR and further considered in this Supplement.
- Taking into account the results of the coastal processes study undertaken to inform this Supplement, the primary management response recommended by the Proponent is the development and implementation of a **Coastal Processes Management Plan**.

6. Summary and Conclusions

6.1. Purpose

The Strategic Assessment of this Browse LNG Precinct proposal will enable the currently known environmental, social and economic issues to be considered now for future developments. A commercial proponent would need to demonstrate, through the submission of a derived proposal based on detailed project design data, that its proposal is consistent with this Strategic Assessment and that there are no new environmental factors or changes to environmental factors that would affect the outcomes of the assessment.

Part 7 (Supplementary Information document) has been compiled to summarise and present additional (predominantly marine focused) technical studies to further inform the public's and EPA's Strategic Assessment of the proposed Precinct. In so doing, this report summarises the studies undertaken, including results, outcomes and conclusions reached. In particular, the accuracy of the impacts proposed in earlier volumes of the SAR, and the adequacy of proposed management and mitigation measures are tested through extensive modelling. These technical reports have been reviewed by independent peer reviewers.

The proposed location for the Precinct, some 60km north of Broome and south of James Price Point, was chosen following an extensive selection process that considered 43 processing options across the Kimberley and alternatives, including the Pilbara and locations outside the State. Four sites were shortlisted following an extensive environmental, heritage, and technical analysis and a rigorous process of consultation with Traditional Owners, environmental groups and other stakeholders. The chosen site was selected following advice from the State Environmental Protection Authority that this was the most environmentally suitable of those sites shortlisted and that impacts could best be managed at this location. Accordingly, it should be noted that these studies, together with those undertaken in earlier volumes of the SAR, are an assessment of what is already considered to be a site with the lowest combined impacts.

6.2. Marine Wastewater Discharge Modelling

The results of the Marine Wastewater Discharge Modelling study were consistent with the assessment outcomes previously described in **Part 3** and **Part 5**. The James Price Point area is characterised by a highly dynamic nearshore coastal environment driven by semi-diurnal tides. Modelling demonstrates that the area experiences regular active flushing to promote rapid dispersion and dilution of discharge streams. Routine wastewater streams anticipated from the BLNG Precinct are readily manageable through achieving discharge minimisation and controls, in order to meet agreed water quality criteria at the boundary of defined mixing zones as committed in the SAR.

6.3. Marine Benthic Primary Producer Habitat Calculations

Despite predictions that the LAU cumulative loss guidelines may be exceeded, the actual magnitude of predicted area losses of BPP communities is relatively low and BPP types that may suffer losses are common within the wider bioregion. Hence, the risk to the ecological integrity of the marine environment within the LAU is considered low. It is noted that as a result of the site selection process identifying a site where the extent of BPPH within the area is low, any predicted losses of BPPH within the LAU will be disproportionately high compared to the magnitude of losses that may occur if the development was sited elsewhere along the coastline, where BPPH is more common. Additionally, the majority of BPPs recorded consist of a mosaic of mixed BPP taxa, with no evidence to suggest that the area contains significant patches of habitats that support distinct or unique community types.

6.4. Hydrocarbon Spill Modelling

Although the likelihood of a significant hydrocarbon spill is very low, the potential environmental impacts are significant. The hydrocarbon spill modelling undertaken to support the SAR demonstrates that the extent of a spill is predominantly driven by prevailing onshore and offshore winds and tidal forces, thereby minimising the likely extent of coastline impacts in the Kimberley region.

Nevertheless, a large hydrocarbon spill could result in significant environmental and social impacts. While State emergency procedures and proponent oil spill contingency plans would be triggered to manage and minimise any impacts that could otherwise occur, preventative measures are introduced at the earliest stages of facility design to

ensure facilities are built to accommodate the range of events that may be encountered. Operational measures are implemented to ensure facilities are regularly maintained and operated to prevent such hydrocarbon spill events, and Government agencies will conduct regular inspections to ensure statutory requirements are met and to identify improvements that can be made to continuously improve environmental and safety outcomes.

6.5. Coastal Processes Modelling

The supplementary coastal process report found that the existing coastal sediment transport regime will be relatively unaffected along the coastline outside the immediate area sheltered by the Precinct. Nonetheless, the port will act as a "sediment sink" and this will result in sediment starvation of local beaches within approximately 2-3km north and south of the port in the short to medium term. It is expected that the predicted impacts to the local coastal geomorphology can be successfully mitigated by the application of best practice management and design measures, consistent with the commitments outlined in the SAR and further commitments in this Supplement (for example the development of an adaptive Coastal Processes Management Plan).

6.6. Impacts

These detailed studies were undertaken specifically to confirm or otherwise the veracity of the findings in regard to environmental factors in relation to:

- Marine Sediments (**Part 3**, **Section 2.2**);
- Marine Water Quality (**Part 3**, **Section 2.3**);
- Benthos including Benthic Primary Producers (**Part 3**, **Section 2.4**); and
- Marine Ecosystem Integrity (**Part 3**, **Section 2.8**).

In addition social factors considered in light of these detailed studies were:

- Commercial Fishing (**Part 5**, **Section 4.5**);
- Aquaculture and Pearling (**Part 5**, **Section 4.6**);
- Sports, Recreation (including recreational fishing) and Land Use (**Part 5**, **Section 4.8**);
- Visual Amenity, Light and Landscape Character (**Part 5**, **Section 4.4**);
- Tourism (**Part 5**, **Section 4.7**); and
- Customary Fishing (**Part 5**, **Section 3.8**).

Environmental and social outcomes of these supplementary studies are found to be largely consistent with those presented in earlier volumes of the SAR. The only additional impact that was identified following this supplementary work was through the modelling of coastal processes, to which it was determined that an adaptive Coastal Process Management Plan would be sufficient to mitigate against adverse environmental or social outcomes. It can therefore be concluded that management plans and other measures identified in earlier volumes of the Strategic Assessment Report should be sufficient to deal with the results of this most recent modelling.

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Annexure A Summary Table of Contents for SAR (all seven parts)

Annexure B Nomenclature, Acronyms, Measurements and Units List

Acronym	Definition
ABS	Australian Bureau of Statistics
ACMC	Aboriginal Cultural Material Committee
AGRU	Acid Gas Removal Unit
AGT	Aero Derivative Gas Turbines
AH Act	*Aboriginal Heritage Act 1972 (WA)*
AHC	Australian Heritage Council
AHD	Australian Height Datum
AIHW	Australian Institute of Health and Welfare
AIMS	Australian Institute of Marine Science
aMDEA	activated methyl-di-ethanol amine
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment Conservation Council
AQIS	Australian Quarantine Inspection Service
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARR	Australian Rainfall and Runoff
ARRP Act	*Agriculture and Related Resources Protection Act 1976* (WA)
ASIA	Aboriginal Social Impact Assessment
ASS	Acid Sulphate Soils
ATSIHP Act	*Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cth)
AWAC	Acoustic Doppler Wave and Current Profiler
Best Practice	The application of the best available mitigation measures that are practicable in the particular circumstances of a proposal to avoid or minimise environmental impact.
BLNG	Browse Liquefied Natural Gas
BLNG Precinct	Browse Liquefied Natural Gas Precinct
BoM	Bureau of Meteorology
BPA	Broome Port Authority
BPEMP	BLNG Precinct Environmental Management Plan
BPMF	Broome Prawn Managed Fishery
BPP	Benthic Primary Producer
BPPH	Benthic Primary Producer Habitat
$Bq\ kg^{-1}$	Becquerels per kilogram
BRAC	Broome Recreation and Aquatic Centre
BRAMS	Broome Regional Aboriginal Medical Service
BRUVS	Baited Remote Underwater Video Surveys
BTEX	benzene, toluene, ethybenzene and xylene
°C	degrees celsius, degrees centigrade
$CaCO_3$	Calcium Carbonate
CAEPR	Centre for Aboriginal Economic Policy Research
CALM	Department of Conservation and Land Management , now DEC
CAMBA	China-Australia Migratory Bird Agreement
Category A	These are the core elements of the BLNG Precinct, including associated infrastructure,

Acronym	Definition
	necessary to process and export hydrocarbons.
Category B	These are indirect activities and actions as a result of the BLNG Precinct that are considered in the impact assessment but do not form part of the approvals process.
Category C	Related projects that are outside the scope of the Strategic Assessment but form part of the cumulative impact assessment.
CCIMP	Committee for Introduced Marine Pest Emergencies
CEMP	Construction Environment Management Plan
CDEP	Community Development Employment Projects
CEO	Chief Executive Officer
CH_4	Methane
CHMP	Cultural Heritage Management Plan
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLG	Cumulative Loss Guideline
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2 -e	Carbon Dioxide Equivalents
CPI	Consumer Price Index
CPRS	Carbon Pollution Reduction Scheme
CSD	Cutter Suction Dredger
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTM	Chemical Transport Model
CWR	Centre for Whale Research
Cwth	Commonwealth
DAFF	Department of Agriculture, Fisheries and Forestry
DAFWA	Department of Agriculture and Food Western Australia
dB	decibels
dB(A)	A-weighted decibels
DCCEE	Department of Climate Change and Energy Efficiency
DDSDMP	Dredging and Dredge Spoil Disposal Management Plan
DEC	Department of Environment and Conservation
DEEWR	Commonwealth Department of Education, Employment and Workplace Relations
DEWHA	Commonwealth Department for the Environment, Water, Heritage and the Arts, now SEWPAC
DHI	DHI Water and Environment Pty Ltd
DIA	Department of Indigenous Affairs
DLGRD	Department of Local Government and Regional Development
DLNG	Darwin Liquefied Natural Gas
DMAG	Dredging Management Advisory Group
DMP	Department of Mines and Petroleum
DoF	Department of Fisheries
DoIR	Department of Industry and Resources
DoLA	Depart of Land Administration
DoP	Department of Planning
DoT	Department of Transport
DoW	Department of Water
DPI	Department for Planning and Infrastructure
DRDL	Department of Regional Development and Lands

Acronym	Definition
DRET	Commonwealth Department of Resources, Energy and Tourism
DRF	Declared Rare Flora
DSD	Department of State Development
DSDG	Dredge Spoil Disposal Ground
DSDMP	Dredging and Dredge Spoil Disposal Management Plan
EAG3	Environmental Assessment Guideline 3
ECHT	Environment and Cultural Heritage Team
EIA	Environmental Impact Assessment
EM Act	*Emergency Management Act 2005* WA)
EMP	Environment Management Plan
EP Act	*Environmental Protection Act 1986* (WA)
EPA	Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
eq.	Acid Equivalents
EVT	Evergreen Vine Thickets
FEED	Front End Engineering Design
FESA	Fire and Emergency Services Authority of Western Australia
FID	Final Investment Decision
FIFO	Fly in/Fly out
FIS	Fishing Industry Impact Study
FLNG	Floating LNG
FM Act	*Fish Resources Management Act 1994* (WA)
Foundation Proponent	Woodside is a potential Foundation Proponent
FRMR	Fisheries Resource Management Regulations 1995
FRP	Filterable reactive phosphorus
G	grams
GBRMPA	Great Barrier Reef Marine Park Authority
GBS	Gravity Based Structure
GCA	Gaffney Cline and Associates
GDEs	Groundwater Dependant Ecosystems
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ	gigajoule
GL	gigalitre
GL/yr	gigalitres per year
GGAP	Greenhouse Gas Abatement Plan
GROH	Government Regional Officer Housing
GRP	Gross Regional Product
GSP	Gross State Product
GST	Goods and Services Tax
GWP	Global Warming Potential
H_2S	hydrogen sulphide
ha	hectare
HAT	Highest astronomical tide

Acronym	Definition
HCWA	Heritage Council of Western Australia
HDD	Horizontal Directional Drilling
HFCs	Hydroflurocarbons
HIA	Heritage Impact Assessment
HNO_3	Nitric Acid
HoA	Heads of Agreement
HONO	Nitrous Acid
HPA	Heritage Protection Agreement
hr	hour
HSE	Health, Safety and Environment
HYPE	Helping Young People Engage
IBRA	Interim Biogeographic Regionalisation of Australia
ICC	Indigenous Coordination Centres
IFPIC	Indigenous Free Prior Informed Consent
IGCC	Integrated Gasification Combined Cycle
ILUA	Indigenous Land Use Agreement
IMO	International Maritime Organisation
IMS	Invasive Marine Species
IMSMP	Invasive Marine Species Management Plan
IP	Important Population
IPCC	Intergovernmental Panel on Climate Change
IS	Integrated System
ISQG	Interim Sediment Quality Guidelines
ITF	Indonesian Throughflow
IUCN	International Union for Conservation of Nature
JAMBA	Japan-Australia Migratory Bird Agreement
JPP	James Price Point
KAMSC	Kimberley Aboriginal Medical Services Council
KAC	Kimberley Aquaculture Corporation
KACS	Kimberley Aged and Community Services
KDC	Kimberley Development Commission
KES	Kullari Employment Services
kg	kilogram
$kgCO_2$-e	kilogram of Carbon Dioxide Equivalents
kHz	kilohertz
KLC	Kimberley Land Council
km	kilometre
kmh^{-1}, km/h	kilometres per hour
km^2	square kilometre
kn	knot
KPP	Kadar Pearson and Partners
kt	kilotonne
LADS	Laser Airborne Depth Sounder
LAT	Lowest astronomical tide
LAU	Local Assessment Unit

Acronym	Definition
LCUs	Landscape Character Units
LGA	Local Government Area
LIA	Light Industrial Area
LiDAR	Light Detection and Ranging
LIGT	Large Industrial Gas Turbines
LNG	Liquefied Natural Gas
LNG Hub	Alternative wording for BLNG Precinct
LoR	Limit of Reporting
LPG	Liquefied Petroleum Gas
LPS	Local Planning Strategy
LSR	Light Sensitive Receptors
LVIA	Landscape and Visual Impact Assessment
$\mu g/m^3$	microgram per cubic metre
$\mu g\ g^{-1}$, µg/g	microgram per gram
$\mu g\ L^{-1}$, µg/L	microgram per litre
µm	micrometre
$\mu g\ m^{-3}$, $\mu g/m^3$	microgram per metre cubed
µMol	micromole
m	metre
m^2	square metre
m^3	cubic metre
m^3/hr	cubic metre per hour
m/s	metres per second
Ma	Mega annum (million years)
mAHD	Metres Australian Height Datum
MDS	Multi Dimensional Scaling
MEG	Mono-ethylene glycol
MF	Marine Facility
$mg\ L^{-1}$, mg/L	milligram per litre
MIGT	Medium Industrial Gas Turbines
MIKE 21AD	A specific advection-dispersion model used by DHI for modelling
MIKE 21HD	A specific ocean / coastal circulation model used by DHI for modelling
ML	megalitre
mm	millimetre
MMbtu	Millions of British Thermal Units
MNES	Matters of National Environmental Significance
MODIS	Moderate Resolution Imaging Spectroradiometer
MOF	Materials Offloading Facility
mol%	Mole percentage
MPA	Marine Protected Areas
MPB	Microphytobenthos
ms^{-1}, m/s	metre per second
MSL	Metres below sea level
Mt	megatonne (million tonne)
Mtpa	million tonnes per annum

Acronym	Definition
MVT	Monsoon Vine Thicket
MWDMP	Marine Wastewater Discharge Management Plan
MWh	megawatt hour
NAGD	National Assessment Guidelines for Dredging
NDT	Northern Development Taskforce
NE	North-east
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NES	National Environmental Significance (i.e. matters of NES)
NGA	National Greenhouse Accounts
NGCC	Natural Gas Combined Cycle
NGER Act	*National Greenhouse and Energy Reporting Act 2007*
NH_3	Ammonia
NH_4	Ammonium
NILF	not in labour force
Nm	nautical mile
NNTT	National Native Title Tribunal
NNW	north-north-west
NO_2	nitrogen dioxide
NO_X	oxides of Nitrogen (NO and NO_2)
NPI	National Pollutant Inventory
NRIF	*National Recreational and Indigenous Fishing Survey*
NRM	Natural Resource Management
NSW	New South Wales
NT	Northern Territory
NTA	*Native Title Act 1993*
NTU	Nephelometric Turbidity Units
NWMR	Northwest Marine Region
NWQMS	National Water Quality Management Strategy
O_3	Ozone
OSCP	Oil Spill Contingency Plan
OSR	Oil Spill Response
PAH	Polycyclic Aromatic Hydrocarbons
PAR	Photosynthetically Available Radiation
PASS	Potential Acid Sulphate Soils
PBC	Prescribed Body Corporate
PCG	Precinct Control Group
PECs	Priority Ecological Communities
Plan	The formal Plan for the BLNG Precinct under Commonwealth legislation (see also Precinct Plan)
PM	particulate matter
PF	Port Facility
PFCEMP	Port Facilites Construction Environnemental Management Plan
PFCs	Perfluorocarbons
ppb	Parts per billion

Acronym	Definition
Ppt	parts per thousand
Precinct Plan	The formal Plan for the BLNG Precinct under Commonwealth legislation (see also Plan)
proponent	Commercial proponents will undertake projects within the Precinct.
Proponent	The Proponent for the Precinct is the Minister for State Development
PRRT	Petroleum Rent Resource Tax
PSD	Particle size distribution
PTS	Permanent Threshold Shift
QA/QC	Quality Assurance/ Quality Control
QMP	Quarantine Management Plan
QLD	Queensland
QRA	Quantitative Risk Assessment
RBA	Reserve Bank of Australia
RBWG	Roebuck Bay Working Group
RIWI Act	*Rights in Water and Irrigation Act 1914*
RMS	Root Mean Square
RNE	Register of National Estate
RO	Reverse Osmosis
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
RORO	Roll on Roll off
RoW	Right of Way
RTO	Registered Training Organisation
SA	Strategic Assessment
SAA	Strategic Assessment Agreement
SAP	Sediment Sampling and Analysis Plan
SAR	Strategic Assessment Report
SE	south-east
SEL	Sound Pressure Level
SEP	State Environmental Policy
SEWPAC	Commonwealth Department of Sustainability, Environment, Water, Population and Community
SF_6	Sulphur Hexafluoride
SIA	Social Impact Assessment
SKM	Sinclair Knight Merz Pty Ltd
SO_x	oxides of sulphur
SO_2	sulphur dioxide
SOPEP	Shipboard Oil Pollution Emergency Plan
SoSA	Scope of the Strategic Assessment
SPL	Sound Pressure Level
SPMT	Self Propelled Module Trailers
SPRAT	Species Profile and Threats Database
SRE	Short Range Endemic
SRG	Stakeholder Reference Group
SSIMP	Strategic Social Impact Management Plan
STI	Sexually Transmitted Infection
SWIS	South West Interconnected System
TAFE	Technical and Further Education

Acronym	Definition
TAPM	The Air Pollution Model
TBT	Tributyltin
tcf	trillion cubic feet
TCU	Thermal Combustion Units
TDS	Total Dissolved Solids
TEC	Threatened Ecological Community
TIA	Tourism Impact Assessment
TJ	terajoules
TM	Thematic Mapper
TN	Total Nitrogen
TOC	Total Organic Carbon
TONC	Traditional Owner Negotiating Committee
ToR	Terms of Reference
TOTF	Traditional Owner Taskforce
TP	Total Phosphorous
tpa	tonne per annum
TPH	Total Petroleum Hydrocarbons
TSHD	Trailer Suction Hopper Dredger
TSS	Total Suspended Solids
TTS	Temporary Threshold Shift
UNDRIP	United Nations Declaration of Rights of Indigenous People
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet
VET	Vocational Education and Training
VMP	Vessel Management Plan
VOC	Volatile Organic Compounds
VSR	Visually Sensitive Receptors
WA	Western Australia
WACHS	Western Australian Country Health Service
WALFA	West Arnhem Land Fire Abatement
WAM	Western Australian Museum
WAPC	Western Australian Planning Commission
WC Act	*Wildlife Conservation Act 1950*
WEED	Weed Education Eradication Delivery
WestPlan-HAZMAT	State Emergency Management Plan for Hazardous Materials Emergencies
WestPlan-MOP	State Emergency Management Plan for Marine Oil Pollution (WestPlan Marine Oil Pollution)
WHO	World Health Organisation
WNW	west-north-west
WONS	Weed of National Significance
Woodside	Woodside Energy Limited
WRC	Water and Rivers Commission, now Department of Water (DoW)
WSW	west-south-west
WWF	World Wildlife Fund
WWTP	Waste Water Treatment Plant