Pluto LNG DEVELOPMENT

Draft Public Environment Report / Public Environmental Review

EPBC Referral 2006/2968

Assessment No. 1632

December 2006

WOODSIDE

Foreword

Thank you for taking the time to review this Draft PER for Woodside's proposed Pluto LNG Development.

The Pluto gas field is located 190 km north-west of Dampier, off Western Australia's Pilbara Coast. The proposed LNG production facilities to be located within the Burrup Industrial Estate are being developed to meet customer demand in 2010.

Through the successful development of resources such as the Pluto gas field, Western Australia is ideally positioned to become one of the biggest LNG exporters in the region, meeting increasing world demand for clean energy.

Woodside has a long record of safe and environmentally sound LNG production with no major incidents in over 15 years operating the North West Shelf Venture. Woodside is committed to developing all projects in a way that is environmentally acceptable and delivers real benefit to the community. While recognising that the world's hydrocarbon reserves are finite, we share the desire of the community to develop these resources in ways that meet the needs of the present, without compromising the environment for future generations.

Members of the public are invited to review this document and provide feedback on our Pluto LNG Development and approach to managing its impacts. Your views are important to us and provide an opportunity to identify further ways in which the Pluto LNG Development will become a best practice LNG producer.

Lucio Della Martina
Director, Pluto LNG Development
Woodside Petroleum Ltd

Invitation to Make a Submission

The Woodside Energy Ltd. (Woodside) owned Pluto gas field was discovered in April 2005 on the North West Shelf. The field is located offshore, approximately 190 km north-west of Dampier, Western Australia. The Pluto gas field has an estimated potential contingent resource of at least 4.1 trillion cubic feet (tcf) of relatively Dry Gas with a small amount of condensate and carbon dioxide (CO_2).

Woodside plans to develop the Pluto gas field through an offshore subsea gathering system tied- back to an offshore platform. Gas will be exported to shore for further processing into liquefied natural gas (LNG) and other petroleum products. The gas processing plant is proposed on the Burrup Peninsula within a designated industrial area known as Lease Area B (Site B); the hydrocarbon storage and export facilities are proposed at Lease Area A (Site A) near Holden Point: directly adjacent to Site B.

The Pluto LNG Development was referred to the Western Australian Environmental Protection Authority (EPA) for assessment in April 2006 and the Commonwealth Department of the Environment and Heritage (DEH) in August 2006 (1 August 2006, DEH reference No. 2006/2968). The proposed development was determined by the DEH to be a 'controlled action' under the provisions of the EPBC Act (24 August 2006). The DEH and EPA subsequently determined that the proposal should be assessed at the Public Environment Report and Public Environmental Review levels of assessment respectively. This document (referred to as the Draft PER) has been prepared to satisfy both state and Commonwealth government jurisdictions and will be submitted to both the Western Australian and Commonwealth governments simultaneously under a joint assessment process This Draft PER meets the requirements outlined in the Environmental Scoping document and Guidelines for both state and Commonwealth assessment processes.

This Draft PER is available for public review for ten weeks from 11 December 06 closing on 19 February 07. Once the public comment period is closed, Woodside will formally respond to comments in a Supplement to the Draft PER. This document along with the Draft PER will constitute the Final PER. Comments from government agencies and from the public will help the DEH and EPA prepare assessment reports in which they will make recommendations to their respective Ministers.

Viewing the PER

The Draft PER can be downloaded from the Woodside website, www.woodside.com.au/pluto or viewed at the following locations:

Department of Environment Library
Level 4, the Atrium
168 St Georges Terrace
Perth WA 6000

Department of Industry and Resources
1st Floor, 100 Plain St
East Perth WA 6000

Research and Information Centre
Department of Industry and Resources
1 Adelaide Terrace
East Perth WA 6000

Department of the Environment and Heritage Library
John Gorton Building
King Edward Tce
Parkes ACT 2600

Ashburton Shire Council
Onslow Public Library
Second Avenue
Onslow WA 6710

Karratha Community Library
Millstream Road
Karratha WA 6714

Battye Library
Alexander Library Building
25 Francis Street
Perth WA 6000

Hard copies of the Draft PER are available at a cost of $10. Electronic copies of the full document are available free of charge. Requests for hard copies or electronic copies should be directed to the Pluto LNG Development Corporate Affairs Assistant on 1800 634 988 or by email at pluto.info@woodside.com.au.

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 DEH and EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Commonwealth *Freedom of Information Act 1982* and the Western Australian *Freedom of Information Act 1992*. Submissions may be quoted in full or in part in agency assessment reports.

Why Not Join a Group?

If you prefer not to write your own comments, it may be worthwhile joining with a group 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 Draft PER. It helps if you give reasons for your conclusions, supported with relevant data. You may make an important contribution by suggesting ways to make the proposal more environmentally acceptable.

When making comments on specific elements of the Draft PER:

- clearly state your point of view
- indicate the source of your information or argument if this is applicable
- 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 Draft PER
- if you discuss different sections of the Draft PER, keep them distinct and separate, so there is no confusion as to which section you are considering
- attach any factual information you may wish to provide and give the details of the source. Make sure your information is accurate.

Remember to include:

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

The **closing date** for submissions is 19 February 07.
Submissions should be addressed to:

Environmental Protection Authority
PO Box K822
PERTH WA 6842
Attention: Richard Sutherland

Contents

Executive Summary

4 Development Description

5 Emissions, Discharges and Waste

8 Existing Terrestrial Environment

9 Terrestrial Environment Impacts and Management

10 Existing Social and Economic Environment

11 Social and Economic Impacts and Management

12 Safety Risk Assessment

List of Figures

List of Tables

Executive Summary

Introduction

This Executive Summary provides an overview of the information presented in the Pluto LNG Development Draft Public Environmental Review / Public Environment Report (Draft PER) prepared by Woodside Energy Ltd (Woodside). The Development is subject to two parallel environmental assessment processes and requires assessment by both the Western Australian and Commonwealth governments in accordance with the *Environmental Protection Act 1986* (EP Act) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Pluto gas field was discovered in April 2005 on the North West Shelf, approximately 190 km north-west of Dampier, Western Australia. Woodside is currently the sole equity holder in permit WA-350-P, which encompasses the Pluto gas field, and plans to develop the field through an offshore subsea gathering system which would be tied back to an offshore riser platform. Gas will then be exported to shore via a gas trunkline for processing (**Figure ES-1**). Development of two separate sites within the Burrup Industrial Estate will be required: a gas processing plant at Site B and a hydrocarbon storage and export facility at Site A. Production is planned to commence in Quarter 4, 2010 (**Figure ES-2**). The gas field and associated facilities are anticipated to have a design life of up to 30 years with potential to be extended through the development and 'tie-in' of other gas fields.

Preliminary exploration drilling suggests that the Pluto gas field has a Dry Gas contingent resource of 4.1 trillion cubic feet (tcf) with small amounts of recoverable condensate and low levels of carbon dioxide (CO_2). The Development will comprise up to two onshore processing trains each with a maximum production capacity of up to 5.9 million tonnes per annum (Mtpa) of Liquefied Natural Gas (LNG), or a total capacity of approximately 12 Mtpa. An expansion of production capacity, which involves the construction of one or more additional LNG trains, is possible but timing (should the expansion eventuate) will be dependent on market and supply variables and hence is not considered as part of this Draft PER.

The gas processing plant is being designed to potentially cater for domestic gas supply (Domgas), should favourable market conditions eventuate. It is anticipated that the Domgas capacity will be in the order of 3.5 to 4 Mtpa; however, this capacity will be refined at a later stage.

Total capital investment in the Development will be between A$6 and A$10 billion.

The Draft PER presents the findings and conclusions of an environmental review for the proposed Pluto LNG Development. The objective of the environmental review process is to ensure that potential environmental impacts associated with the proposed activities are identified, assessed and appropriately managed. Accordingly, relevant preventative and management measures have been developed and will be implemented to ensure that adverse environmental impacts are managed to an acceptable level. These management measures will continue to be further developed and refined during detailed design and incorporated into detailed Environmental Management Plans (EMPs).

Figure ES-1 Location of Proposed Development Area

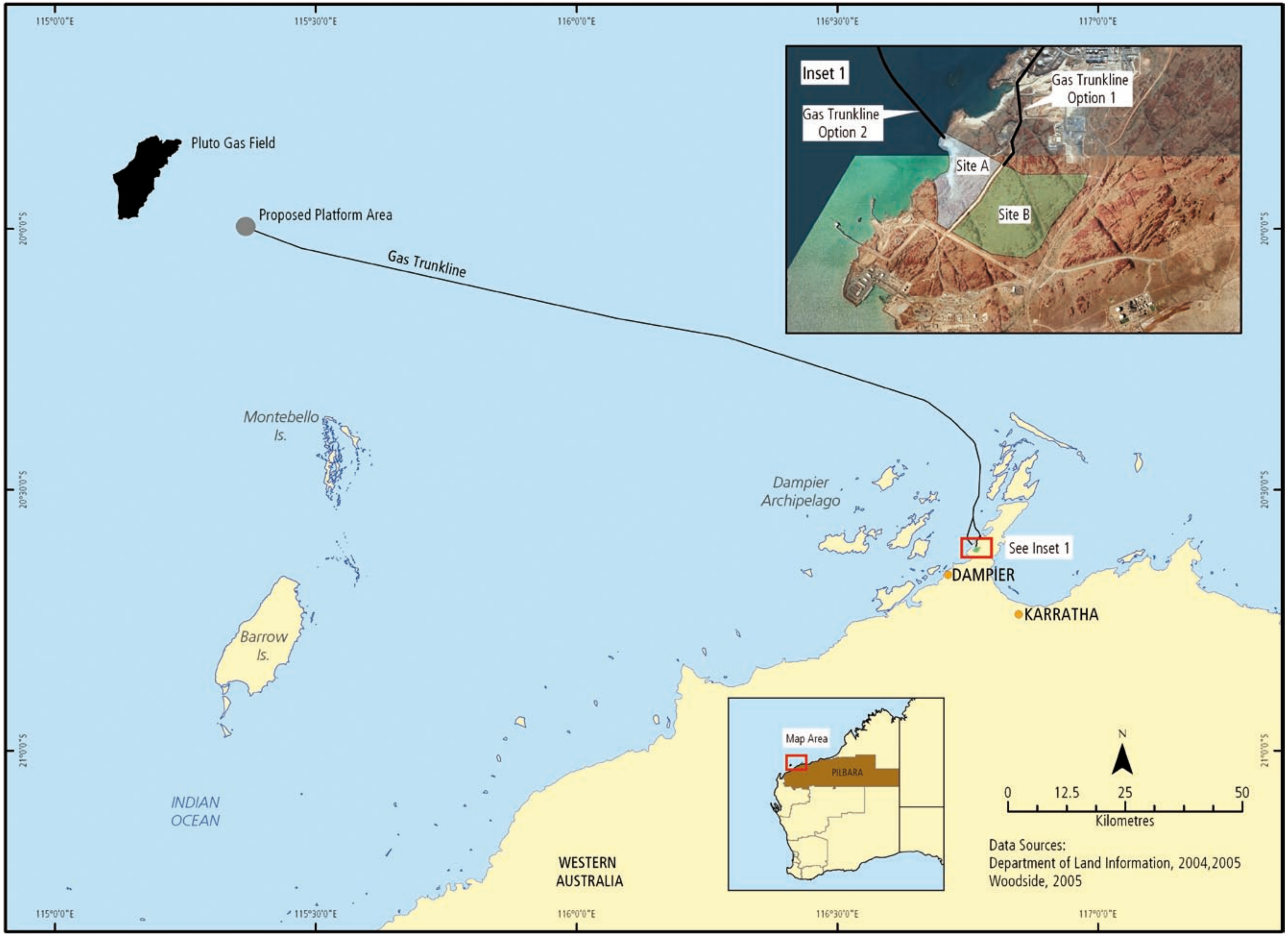
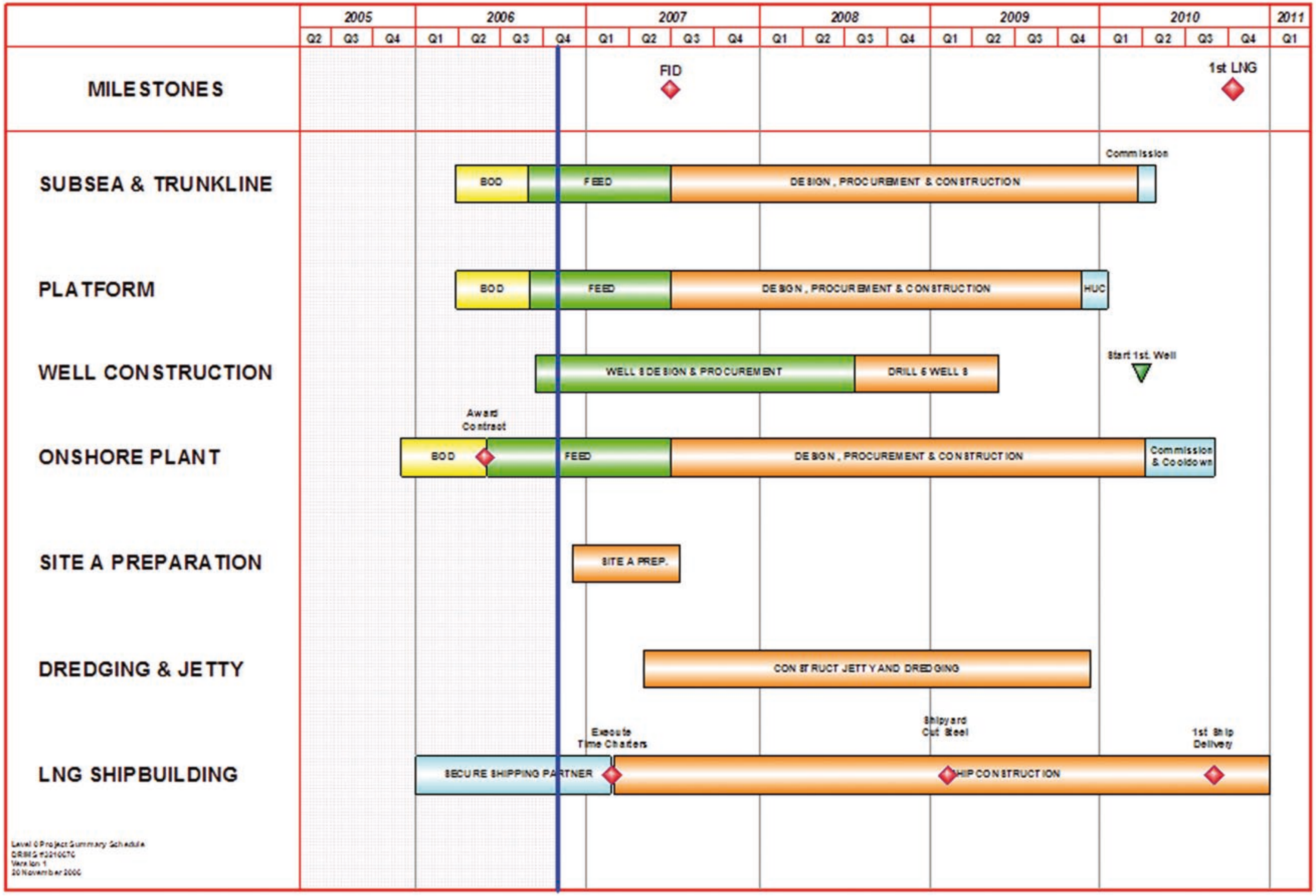


Figure ES-2 Preliminary Development Schedule



Development Proponent

Woodside is the proponent for the proposed Pluto LNG Development and will also be the owner and operator. Woodside is Australia's largest publicly traded oil and gas company and is one of the nation's most successful explorers, developers and producers. The company operates Australia's biggest resource development, the North West Shelf Venture (NWSV) in Western Australia, a project that produces approximately 40% of Australia's oil and gas.

Since the early 1980s, the company has overseen expenditure on the NWSV of more than A$19 billion as the Venture has grown into one of the world's leading LNG exporters. Over the past 50 years, Woodside's business has grown to cover four continents with core areas of focus being Australia, the United States and Africa. In Australia, the company has major exploration and development interests in Western Australia, including the new oil province in the Carnarvon Basin which includes the Enfield, Vincent and Laverda fields, and significant gas discoveries in waters off Victoria and the Northern Territory.

In the United States, Woodside produces gas and oil from fields in the Gulf of Mexico, where it also has an extensive exploration programme in the continental shelf and deep water. Woodside has offices in Houston, Texas; Covington, Louisiana; and Los Angeles, California. In Africa, Woodside is operator of the Chinguetti oil project off Mauritania. It is also operator of the Tiof, Tevet and Banda oil and gas discoveries in the same region, and has exploration interests in Libya, Kenya, Sierra Leone, Liberia, Canary Islands and Brazil, and is a participant in major producing gas and condensate fields in Algeria.

Woodside operates three floating production, storage and offloading facilities: the *Northern Endeavour* is based on the Laminaria and Corallina oil fields in the Timor Sea; the *Cossack Pioneer* is based on the North West Shelf and the *Berge Helene* is based at Chinguetti. Woodside also operates the Legendre, North Rankin and Goodwyn platforms off Western Australia.

By 2008, the company expects to be producing the equivalent of up to 80 million barrels of oil and gas a year from its LNG, oil, condensate, liquefied petroleum gas and natural gas projects around the world. It also expects to be operating five floating production systems, five major offshore platforms and five LNG processing trains.

At 30 September 2006, Woodside was capitalised at more than A$26 billion. It employs more than 3200 people and has its headquarters in Perth, Western Australia. Woodside has a long record of safe and environmentally sound LNG production with no major incidents in over five years operating the NWSV. This record has been recognised through numerous awards.

Woodside has a corporate Environmental Policy that provides a public statement of its corporate commitment to protecting the environment during all activities, including offshore exploration and production. The company also has a number of more specific environmental guidelines.

Development Rationale

The Pluto gas field is being developed to meet a market opportunity in late 2010. Woodside discovered the field in April 2005 and since that time has moved quickly to progress the Development and secure foundation LNG customers. Two Heads of Agreement have been signed with Tokyo Gas and Kansai Electric, for a combined total of 3.25 to 3.75 Mtpa of LNG, with deliveries starting by the end of 2010 and continuing for five years with an option to extend for a further five years. The balance of the Pluto gas reserves will be sold on the global market.

The Pluto LNG Development is located in an area where significant offshore reserves of gas exist, although not all reserves are commercially viable to develop on their own. Woodside has developed a commercial model for the Development that provides for other resource owners access to Pluto LNG Development foundation infrastructure with the intention of creating the 'Burrup LNG Park' as a potential aggregator for otherwise stranded or yet to be discovered gas fields in the region. Should this occur the Pluto LNG Development has the potential to minimise the long-term footprint of onshore LNG processing facilities in the region.

The Pluto LNG Development will deliver a range of significant economic benefits to the local area, Western Australia and Australia. Up to 3000 direct jobs are expected to be created during the peak construction phase of the Pluto LNG Development, with up to 200 long-term jobs during operations. Additional benefits will include the creation of training, employment and business opportunities, increased revenue to government and flow-on economic activity.

Australia's Position in the Global LNG Market

With an estimated 153 tcf of discovered gas, Australia has yet to fully capitalise on its potential as a global LNG player.

A strong reputation for reliable supply of LNG has been built by the NWSV, which has focussed predominantly on export to Asian markets. Recently a second project, based on the Bayu-Undan field in northern Australia, came online.

The Pluto LNG Development represents a significant opportunity for Australia to significantly boost its profile in the global LNG market. As well as meeting a market window opportunity to supply premium customers based on the development of the Pluto gas field, the development provides the foundations for a new 'LNG hub' in the Carnarvon Basin. By adopting an open access model which provides the technical and commercial flexibility to aggregate currently stranded regional gas, the Pluto LNG Development has the potential to significantly increase Australia's LNG exports.

Potential Regional Development

Woodside has interests in a number of prospective permits to the north and west of WA-350-P and the Pluto LNG Development's offshore infrastructure will represent a potential tie-in point for any regional gas discoveries. The Pluto LNG Development provides a critical conduit for maximising the value of gas from future discoveries.

The Pluto LNG Development offshore facilities will be constructed to enable tie-in of third party fields should this be commercially attractive. Over 70 tcf of undeveloped Dry Gas has been discovered in the Carnarvon Basin excluding the NWSV acreage. Depending on the sequence of projects in the region, some of these resources may be available to be produced through the Pluto LNG Development infrastructure. Onshore, approvals are being sought and capacity is being optimised with a view to future gas processing opportunities. Discussions are being progressed with the owners of adjacent fields to pursue early commitment to tie-in to the Pluto LNG Development infrastructure. Potential synergies with the existing NWSV Karratha Gas Plant will continue to be explored.

Stakeholder Engagement

Woodside has consulted with a broad diversity of stakeholders during the preparation of this Draft PER, including community groups, government departments, business representatives, Indigenous groups and individuals. Stakeholders were consulted using a range of methods including community meetings, correspondence, telephone conversations and workshops with the aim of:

- briefing stakeholders on the Development concept and fostering an understanding of Woodside's objectives and timeline for the Development
- presenting stakeholders with the key environmental factors associated with the Development and potential impacts and proposed environmental management strategies
- gaining feedback from stakeholders on the environmental, social and heritage aspects of the proposed Development
- providing Woodside with the opportunity to demonstrate commitment to achieving a high level of environmental performance through its approach to environmental management for the Development.

Woodside aimed to directly engage stakeholders early in the project planning and environmental assessment processes and will continue throughout all phases of the Development to ensure that issues raised by stakeholders are identified and appropriately addressed.

Development Alternatives

Woodside has assessed a range of alternatives for the Pluto LNG Development. For the onshore components of the Development, including the proposed storage facilities, this has included the conduct of a comprehensive regional assessment or site selection study of potential development locations and investigation into design options at alternative development sites.

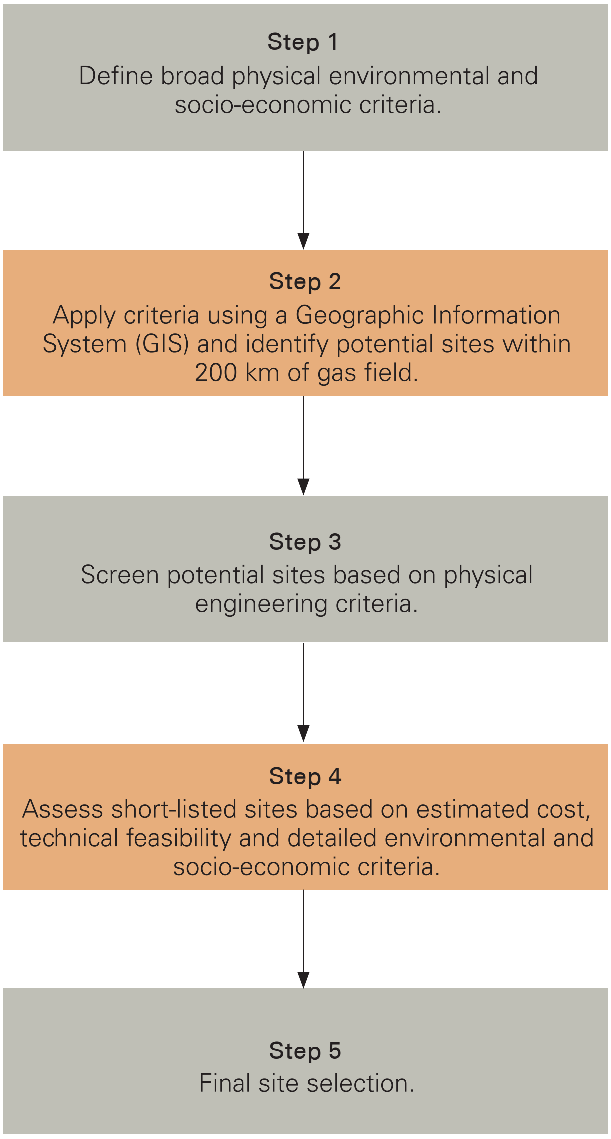
The site selection process followed a logical step-wise approach as illustrated in **Figure ES-3**. The approach used was to identify a number of suitable sites that generally complied with development, environmental and socio-economic criteria and then analyse the alternatives to converge on a shortlist of sites that could be taken forward to final site selection. Extensive engineering studies have been conducted to support the site selection study. In addition, alternative development locations have been discussed with government, non-government organisations (NGOs) and local communities.

Twelve potential regional development sites were assessed (**Figure ES-4**). Each of the 12 sites were subject to an 'on-ground' inspection and screening process, which considered all sites from an engineering feasibility perspective. Physical parameters included sufficient elevation, ruggedness of topography, access to deep water, adequate sheltered water, sufficient Development area (200 ha) and access to infrastructure. The results of the engineering studies combined with an assessment of cost, environmental and socio-economic factors demonstrate that Site A and Site B within the Burrup Industrial Estate present the best available location for the Pluto LNG Development.

In particular, the advantages of development within the Burrup Industrial Estate include:

- Location within a designated industrial estate with significant existing common-user infrastructure.
- Certainty over Native Title which has been extinguished on the Burrup Peninsula.
- Significantly lower development cost compared to Onslow. Construction of a 3 km jetty and dredging a lengthy access channel (approximately 19 km) at Onslow results in substantial additional capital cost over the Burrup Peninsula option.
- Proximity to the regional centres of Karratha and Port Hedland which contain existing community infrastructure with a greater capacity to cope with a major development.
- Existing knowledge of the Burrup Peninsula. There have been numerous proposals and associated studies conducted on the Burrup Peninsula over the years resulting in a good understanding of the existing ecological, socio-economic and physical attributes, including metocean and geology, and the potential risks associated with development in the area.
- Ability to draw on Woodside's experience in operating the NWSV Karratha Gas Plant on the Burrup Peninsula.

Figure ES-3 Site Selection Process



Pluto LNG Development

Offshore development drilling will initially comprise of three to seven wells with up to 12 in total as the field matures. Wellstream products will be delivered to an offshore riser platform via manifolds and flowlines. The riser platform will not support any processing facilities but would be equipped with control and chemical dosing systems. It is likely that as the reservoir pressure declines the Development would require gas compression facilities to be installed following 4–10 years of operation. This will most likely entail a second platform; environmental approvals for the second platform are outside the scope of this Draft PER and will be sought separately in the future.

All recovered wellstream gas and liquids would then be transferred to shore by gas trunkline for treatment at the gas processing plant at Site B (**Figure ES-5**). Once received at the gas processing plant, the natural gas, condensate and produced water (which comprises formation water and condensed water) will be separated. The gas will be processed into LNG, and the LNG and condensate piped to the storage and export facilities located at Site A. From Site A tankers will load and export product through a purpose-built jetty and navigation channel. During operations it is anticipated that LNG tankers will export product once every five days and condensate tankers four times a year.

During construction activities, laydown areas will be required to support machinery, equipment and materials. These areas will be located within Site B.

The Pluto LNG Development will require marine infrastructure to support both construction and operation activities. The nearshore infrastructure will broadly comprise:

- a jetty comprising of a bridge, either with or without a causeway
- an offloading berth for LNG and condensate tankers
- a dredged navigation channel consisting of a channel, turning basin and berth pocket
- waste water discharge pipeline located at end of jetty.

Dredging will be required along the navigation channel route to allow safe approach, berthing and departure of the LNG tankers and condensate tankers. It is anticipated that the navigation channel will require deepening to 13.5 m depth to accommodate deep-drafted vessels. It is expected that dredging of the navigation channel, turning basin and berthing pocket will produce between 10 and 12 Mm^3 of spoil. In addition, it is expected that dredging for the nearshore trunkline will produce an additional 1 to 2 Mm^3 of spoil from within the Dampier Port Authority (DPA) limits. The total expected quantity of spoil from within DPA limits is therefore expected to be between 11 and 14 Mm^3.

Figure ES-4 Regional Site Locations

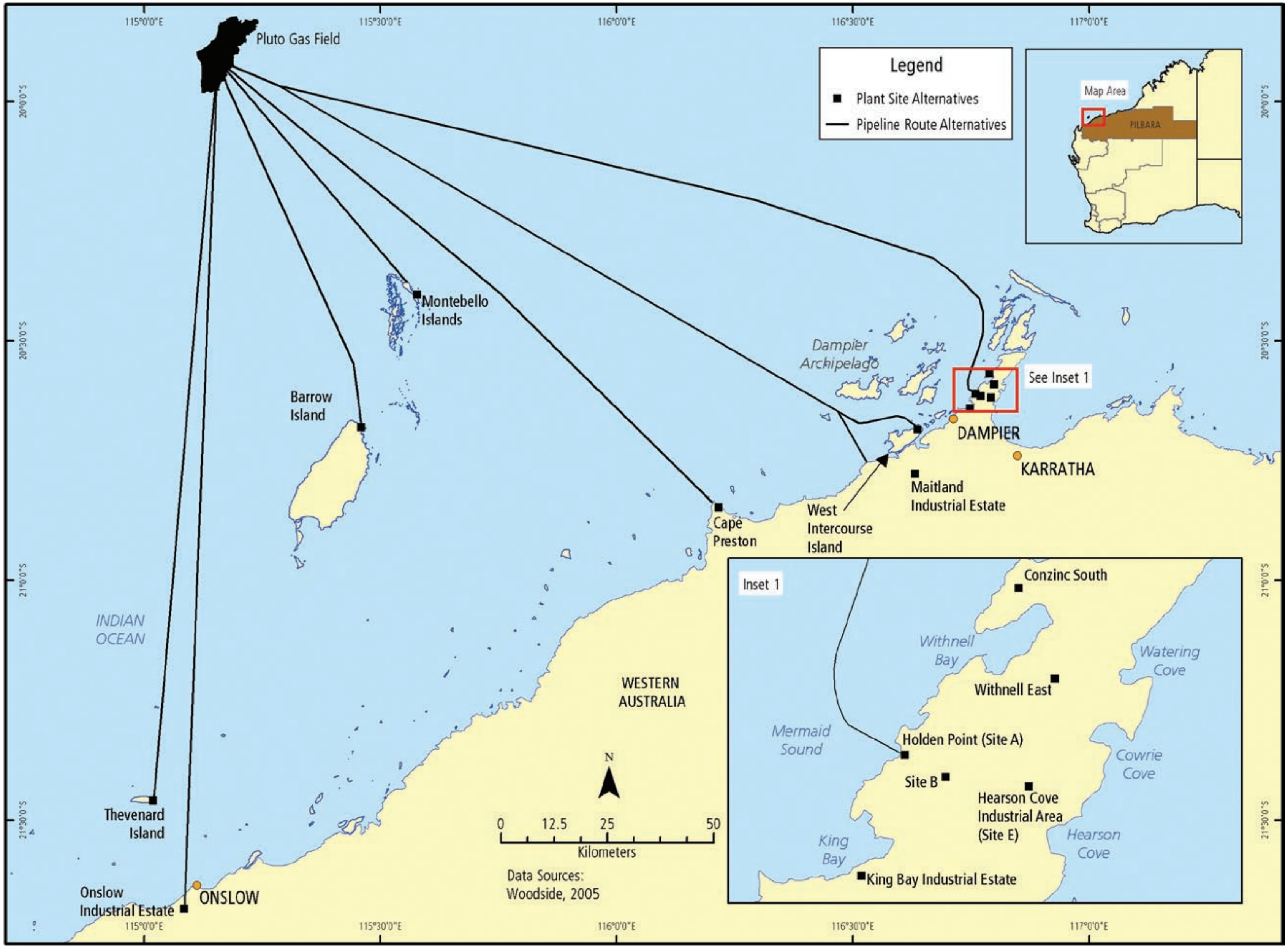


Figure ES-5 Development Concept

Environmental Baseline Studies

Several environmental studies and field surveys were undertaken as part of the environmental review process to provide site specific baseline information and to gain a better understanding of the potential environmental impacts associated with the Pluto LNG Development. Baseline field surveys included:

- a sea turtle habitat survey at Holden Point beach, Site A
- an offshore marine environmental survey within the Pluto gas field and platform area
- sampling and assessment of sediment chemistry characteristics in proposed dredging and spoil disposal areas
- a nearshore marine and intertidal environment survey
- deployment of an underwater noise logger at the Pluto gas field to record ambient noise characteristics
- a flora and vegetation condition assessment of the onshore gas trunkline route
- vegetation and flora surveys of Site B and Site A
- a land and aquatic snail surveys of Site B and Site A.

Based on the findings of all these studies impact assessments were undertaken to determine the predicted impact on the receiving environments as a result of the proposed Development. The assessment covered all potential impacts associated with the construction, operation and decommissioning phases of the Development.

Existing Marine Environment

Physical Environment

The North West Shelf is 95 000 km^2 of continental shelf extending from the North West Cape to the Arafura Sea. The Dampier Archipelago lies within the North West Shelf and consists of 12 major islands and many smaller islands. During summer, prevailing winds are from the north-west and south-west, changing to south-easterlies over winter. Mean water temperatures range from 23°C in winter to 28°C in summer, and there is relatively low rainfall, although heavy downpours can occur during tropical cyclones and depressions.

The bathymetry of the North West Shelf in the vicinity of the Pluto LNG Development is characterised by a gradually sloping continental shelf that extends some 150 km to a shelf break where the seabed drops to the abyssal floor with depths of 4000–5000 m. Bathymetry at the Pluto gas field is characterised by a number of submarine canyons tending east-west across the slope and a series of rock pinnacles located at approximately 300 to 500 m depth. The Dampier Archipelago is entirely contained within the 30 m isobath and has a relatively complex bathymetry.

The relatively turbid shallow waters of the Dampier Archipelago contrast with the deeper clear offshore waters on the continental shelf. Sediments of the North West Shelf are primarily comprised of silty sands on the outer shelf with calcareous sands and gravels over calcarenite pavement on the inner shelf and in the Dampier Archipelago.

Circulation on the North West Shelf is dominated by large tides and is influenced by the Leeuwin Current and the Indonesian Throughflow.

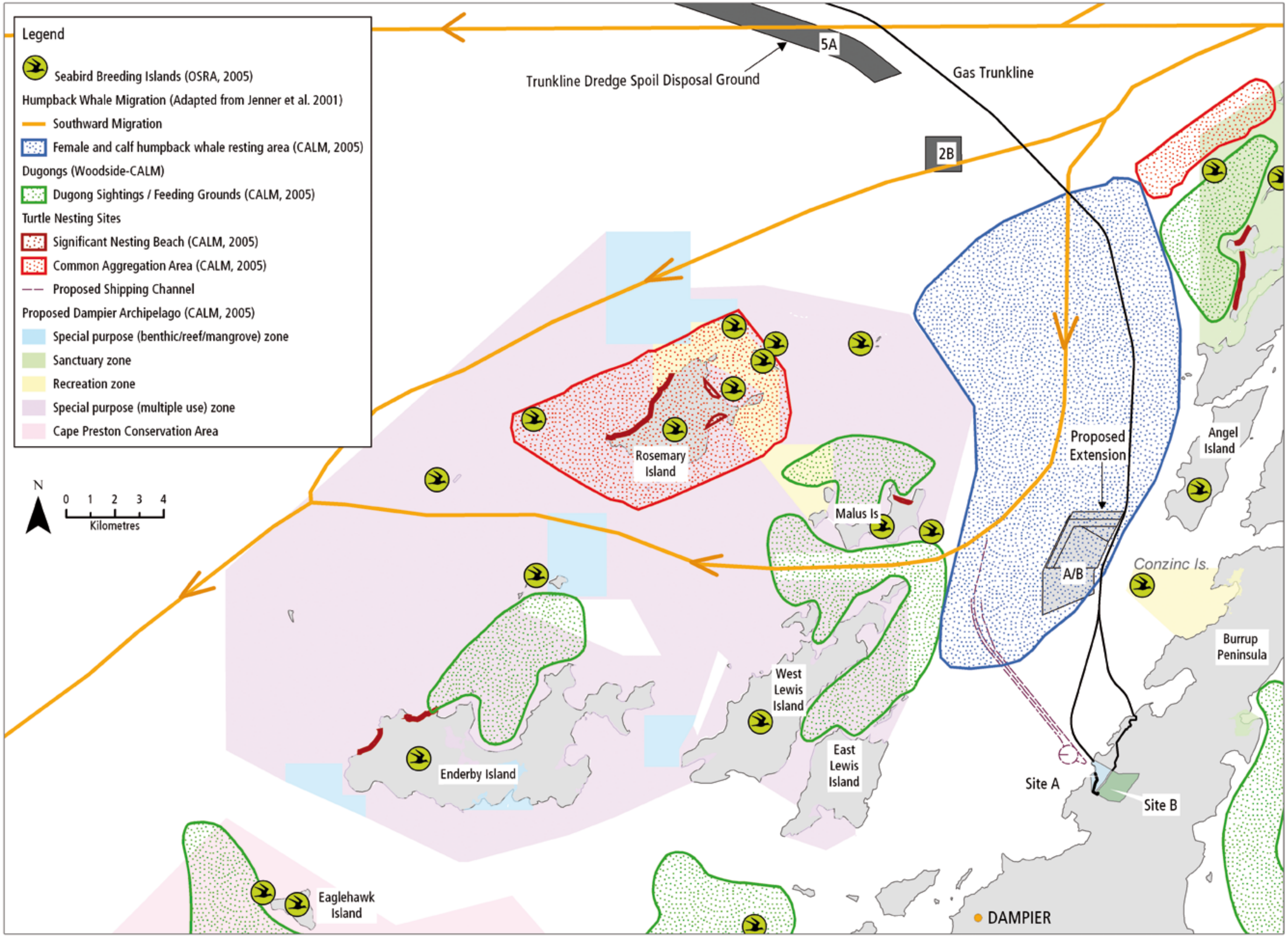
Ecological Environment

Benthic biological productivity on the outer continental shelf and slope is low as a consequence of water depth and associated light attenuation, low nutrient availability, and the lack of hard substrates. Seafloor communities in deeper waters are generally unproductive, and even with the relatively clear open ocean conditions in the area, light penetration to the seabed at a depth of 100 m is generally insufficient for the Development of plants and coral reef. An exception is the presence of deep sea pinnacles in approximately 300 m of water, created by a deep water coral which has been identified as a species of *Lophelia*.

Marine mammals and seabirds travel through the area, for example, humpback whales (*Megaptera novaeangliae*) migrate in a northerly direction through the permit area on the way to winter breeding grounds. During their southerly migration they keep close to the mainland and rest in Dampier Archipelago on their journey to Antarctic summer feeding grounds. Blue whales are also known to move through the offshore Development area. The benthic biota is characterised by sparse but highly diverse infaunal and epifaunal communities.

There is a high diversity of nearshore marine habitats in the Dampier Archipelago and in the coastal waters of the North West Shelf. Habitats range from broad expanses of intertidal mud banks and sandy beaches, intertidal and subtidal coral and rocky reefs and pavements, to deeper channels between coastal islands and reefs created by the scouring of strong tidal currents. Intertidal and shallow subtidal habitats are extensive and well developed along the Pilbara coastline, and include mangals, coral and rocky reefs, algae and ephemeral seagrass beds and invertebrate filter feeding communities (Wells et al. 2003; CALM 2005). The Dampier Archipelago provides habitat for a number of EPBC Act listed species including sea turtles, dugongs and seabirds (**Figure ES-6**).

Figure ES-6 Environmental Sensitivities in the Vicinity of the Pluto LNG Development



Existing Terrestrial Environment

Physical Environment

The Pilbara coastal region, extending from the Exmouth Gulf to north of Port Hedland, is environmentally varied and complex, and is generally rugged, inaccessible and remote from infrastructure. The key characteristics of the region are:

- Cyclonic activity occurs between November and April with attendant storm surge and flooding of rivers and coastal plains.
- Most of the region is occupied by Precambrian basement rocks with the majority of the coastline being exposed Precambrian igneous rock.
- Rainfall is unreliable and sporadic resulting in ephemeral creeks and rivers.

Ecological Environment

Vegetation and Flora: Regional flora and vegetation surveys have been undertaken for the Burrup Peninsula and adjoining areas of the Dampier Archipelago by Trudgen (2002) which concluded that the Burrup Peninsula contained some 200 vegetation associations and a high number of geographically restricted or uncommon species.

Local flora and vegetation surveys have been undertaken for all of the main Development areas, either by Woodside or previous proponents. The vegetation associations within the Development area are very diverse, reflecting the range of habitats present. Some of the vegetation types are not well represented on a local or regional scale. The following habitats and related vegetation associations were recorded:

- Site B was surveyed in two sections. Site B South had five habitats and 26 vegetation associations (Astron 2005b) and Site B North had six habitats and 43 vegetation associations (ENV 2006a).
- Site A was found to have seven habitats and 33 vegetation associations (Astron Environmental 2005a).

The gas trunkline from the existing NWSV Karratha Gas Plant to Site B was completely degraded; no intact vegetation associations were found (ENV 2006b).

One Priority flora species, *Terminalia supranitifolia* (Priority 3), was located within the Pluto LNG Development area. No Declared Rare Flora or flora species listed under the EPBC Act were recorded. In total, 16 other plant species of conservation interest were recorded in the Pluto LNG Development area. These species are not protected by any specific legislation but are identified as being of conservation interest for reasons such as: being uncommon or newly discovered; being poorly collected; populations which may be at the end of the range of species; or populations which may be a significant extension of the known range of the taxa concerned (Trudgen 2002).

Weeds: A number of weed species have been recorded throughout the Burrup Peninsula and also on the surrounding islands of the Dampier Archipelago. Four weed species were recorded in the Pluto LNG Development area, with the most common being kapok (*Aerva javanica*) and buffel grass (*Cenchrus ciliaris*):

- Kapok was recorded within the gas trunkline route, as well as Site B and Site A. It was particularly abundant along the gas trunkline and remnant coastal dunes in Site A.
- Buffel grass was recorded within Site B and Site A.
- Spiked malvastrum (*Malvastrum americanum*) was recorded once within the gas trunkline route from the NWSV Karratha Gas Plant to Site B.
- Milk thistle (*Sonchus oleraceus*) was recorded at Site A but was not abundant.

Terrestrial Fauna: There are many types of fauna habitats on the Burrup Peninsula. Inland habitats include rocky outcrops, rocky scree slopes, drainage gullies and valleys and coastal habitats include mangals, beaches, saline flats and rocky coastlines. The fauna of the Burrup Peninsula has been well surveyed and documented, and most vertebrate species are widespread throughout the Pilbara region. At least 300 vertebrate species have been recorded on the Burrup Peninsula. Approximately 36 mammal species (including four introduced species), 186 bird species, 78 terrestrial reptile species and four amphibian species may inhabit the area; however, none of these are known to be restricted to the Burrup Peninsula (Worley Astron 2005).

Declared threatened terrestrial fauna species that have the potential to occur within or near the Pluto LNG Development are the northern quoll (*Dasyurus hallucatus*), Pilbara leaf-nosed bat (*Rhinonicteris aurantius*, Pilbara Form), Pilbara olive python (*Liasis olivaceus barroni*) and the peregrine falcon (*Falco peregrinus*).

Surveys for land and aquatic snails have been undertaken at Site B and Site A (Slack-Smith 2005; Biota Environmental Sciences 2006a; 2006b). The surveys recorded seven terrestrial species: *Quistrachia legendrei*, *Rhagada* sp., *Pupoides* sp.? *Pupoides beltianus*, *Pupoides contraries*, *Gastrocopta pilbarana*, *Stenopylis coarctata* and *Amerianna* sp. One species of planorbid freshwater snail belonging to the genus *Isidorella* was found within Site B; no other freshwater snails were recorded (Biota Environmental Sciences 2006b).

Existing Social and Economic Environment

Aboriginal Heritage: The Western Pilbara Region and associated islands contain a prolific and diverse range of Aboriginal heritage sites and objects. It has been estimated that the Dampier Archipelago may contan approximately one million rock art images (petroglyphs), with an overall density of 17 to 77 Aboriginal heritage sites per square kilometre.

Archaeological heritage surveys have been completed over Site A and Site B by Australian Cultural Heritage Management (ACHM). The Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera and the Wong-Goo-Tt-Oo groups have also completed ethnographic heritage surveys at both development sites.

During the archaeological survey a total of 80 archaeological sites were recorded at Site A, including 47 previously unrecorded sites and 33 previously recorded sites. The survey found that these sites include a total of 1240 rock art panels and 2488 individual motifs. The majority of sites are distributed along the eastern and south-western margins of Site A associated with rocky hills, intervening valleys and watercourses, and will not be impacted by the Development (**Figure ES-7**). The development that Woodside is proposing for Site A will occur over 15 to 20 ha in the northern portion of Site A where heritage sites occur in lower densities and are mostly of lower significance than in other areas of the site. The Site A ethnographic heritage surveys found large site complexes in the southern area and the eastern margin of the site. The beach area is considered to be highly significant.

A total of 107 previously unrecorded archaeological sites were recorded during the archaeological survey of Site B in June 2006. In addition to these, eight sites previously recorded by the Department of Indigenous Affairs (DIA) were verified as being located within Site B. Fourteen other archaeological heritage sites, recorded by a previous development proponent, were also verified as being located within Site B. In total, the archaeological heritage survey identified a total of 129 archaeological heritage sites within Site B, of which 105 have rock art components that total an estimated 220 rock art panels (rock faces with one or more rock art engravings) that comprise 356 individual rock art images.

The Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera group ethnographic survey resulted in the identification of two large and highly significant ethnographic site complexes that span the margins of Site B and in particular the southern and central valley systems. At the time of writing this Draft PER Woodside was not in receipt of the Wong-Goo-Tt-Oo's Site B heritage survey report so is unable to document the key findings of that survey.

European Heritage: Buildings and places of heritage value are those that have a defined connection to the early European settlement and development of Karratha and its surrounds. The nearest such sites are the Dampier Fire Station and the Kindergarten and Church, which are located approximately 7.5 km from Site A and Site B.

Land Tenure and Land Use: Site B and Site A are currently vacant and zoned for industrial use under the Burrup Land Use Plan and Management Strategy (BPMAB 1996). Site B includes an easement for the Dampier Bunbury Natural Gas Pipeline although the current pipeline is located to the east of the Site B lease area.

Protected Areas: There are several existing marine protected areas in the vicinity of the Pluto LNG Development including Ningaloo Reef Marine Park, Muiron Islands Marine Management Area and Cape Range National Park. The Pluto LNG Development does not directly impinge on any national parks, nature reserves or conservation areas. Two proposed marine protected areas in the vicinity of the Development are the Cape Preston Marine Management Area and the Dampier Archipelago Marine Park.

Existing terrestrial protected areas in the vicinity of the Development include a number of island nature reserves which are encompassed in the Dampier Archipelago Nature Reserve. The Dampier Archipelago Nature Reserve is vested in the National Parks and Nature Conservation Authority, and managed by the Department of Environment and Conservation. The closest National Park to the Pluto LNG Development area is currently the Millstream-Chichester National Park, approximately 65 km to the south-east.

Site A and Site B are located approximately 2 km from Conservation, Heritage and Recreation Area 2, as allocated by the Burrup Land Use Plan and Management Strategy (BPMAB 1996). The Burrup Peninsula and Hearson Cove are registered on the Heritage Council of Western Australia's 'Places Database', which includes details of places considered to have cultural heritage significance.

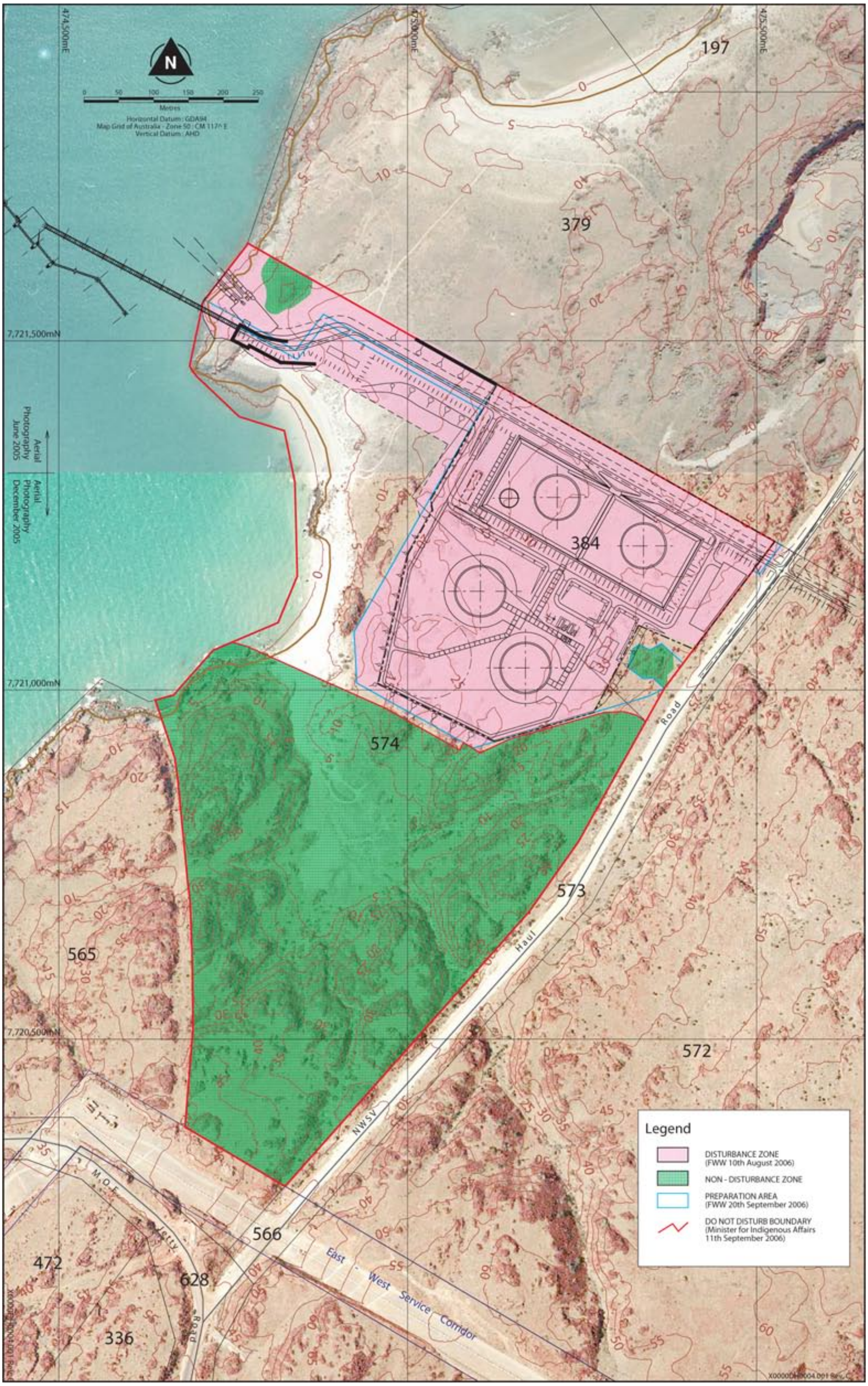
Fisheries: Commercial fisheries on the North West Shelf consist of prawn and finfish trawling, finfish trapping and netting. The principal fisheries in the Pilbara region target tropical finfish, tuna and other large pelagic species and crustaceans (prawns and scampis) as well as pearl oyster.

Recreational fishing is popular in the Dampier Archipelago where several methods are used, including line fishing, netting and spear fishing. Offshore islands including coral reef systems and continental shelf waters support species of major recreational interest including sharks, tunas and billfish.

Infrastructure: The Pilbara region is supported by modern and efficient infrastructure, including energy, water, transport and communications services. The Port of Dampier is one of Australia's largest ports by tonnage facilitating the export of iron ore, salt, LNG, liquid petroleum gas and condensate. Karratha, Dampier, Roebourne and Wickham receive their water supplies from the Millstream natural aquifer and the Harding Dam. The Water Corporation, in conjunction with Burrup Fertilisers, has recently commissioned a desalination water supply system with plans to expand this plant into a multi-user system.

Marine Traffic: Several significant shipping routes exist in the vicinity of the Pluto gas field and offshore trunkline options. Mermaid Sound sees most of the marine traffic in the Dampier Archipelago. Approximately 2000 vessels travelled through Mermaid Sound in 2004/2005.

Figure ES-7 Site A Non-Disturbance Area



Tourism and Recreation: The Pilbara region is becoming an increasingly popular visitor destination with average annual visitor numbers for 2003–2004 of 274 500 and 29 300 for domestic and international tourists, respectively. The region's coastline is also popular for aquatic activities, and several protected coves and bays located on the Burrup Peninsula are used for recreational purposes by the local community. Hearson Cove is one of the more popular beaches in the area.

Visual Amenity: A number of landscape character types have been identified within the southern extent of the Burrup Peninsula including industrial complexes, tidal flats, inlet and saline flats, high scree slopes and rock outcrops. Potential receptors of visual impacts are business and industrial premises, the road network and recreational rights-of-way and facilities.

Social Environment: Karratha had a population of 10 776 in 2001 and is estimated to reach 12 800 in 2006 (Shire of Roebourne 2004). Dampier had a population of 1490 in 2001. The Pilbara economy is crucial to the state, providing three of the largest export revenue earners: iron ore, LNG and oil.

Economic Profile: The Western Australian economy including the Pilbara is currently experiencing boom conditions. A large proportion of business investment has been occurring in the Pilbara—related to major expansions in iron ore mine capacity, as well as the construction of additional LNG trains for the NWSV Karratha Gas Plant. Further expansions are expected, with iron ore and LNG production forecast to double over the course of this decade. As a result, the Pilbara region is also experiencing exceptional economic growth. Considerable employment opportunities have been developed within the Shire of Roebourne from resource development. The highest employment industry within the Shire is mining, employing 18% of residents. The construction industry provided 12% of residents with employment. Other significant industries include retail, government and manufacturing (ABS 2001).

Impacts and Management

The Draft PER identifies the potential impacts from the proposed Pluto LNG Development and associated preventative and management strategies that will be implemented to reduce impacts to an acceptable level.

Activities associated with the Development have been assessed through a comprehensive impact assessment process which has been verified using the Woodside corporate risk assessment tool. This process allows potential environmental impacts to be systematically identified and considered on the basis of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk to the environment.

It should be recognised that a formal risk assessment of environmental issues is only one of the tools employed to identify and rank the key environmental impacts of the Pluto LNG Development. The value of the risk assessment is as a high-level screening tool, to identify the impacts that require detailed assessment. The results of the risk assessment should not be interpreted in isolation from the broader assessment process described within the Draft PER.

The impact assessment concluded that the vast majority of impacts can be categorised as having short-term consequences on the environment and will be managed through the implementation of routine mitigation and management measures. Priority has been given to development of management measures to address the impacts described in the following sections.

Marine Impacts and Management

The marine environmental impacts are summarised in **Table ES-1**, along with associated preventative and management measures.

To address higher priority impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to an acceptable level. Key mitigation and management measures for marine impacts are summarised in the following section:

Seabed Disturbance During Construction Activities: Various activities will result in seabed disturbance such as trunkline laying, trenching and possible rock-dumping within the Dampier Archipelago, construction of a jetty and dredging for a shipping channel and turning basin.

Several management measures have been identified to minimise the areas of seabed disturbance. The final trunkline route will minimise disturbance to sensitive areas and an anchor management system will be utilised which will enable accurate positioning of anchors to avoid or minimise impact to benthic communities. Support vessels will not anchor outside designated anchoring areas unless in an emergency situation. Anchoring over areas of significant seabed, such as coral habitat, will be avoided.

Physical Presence of Vessels: Construction and operation vessels represent a collision risk for sea turtles and marine mammals within Dampier Archipelago and the wider Development area.

The potential for collisions between marine mammals (for example, dolphins and whales) and vessels is considered slight given that these species are likely to exhibit behavioural and avoidance responses and the majority of vessels will be moving at restricted speeds within port limits in accordance with DPA requirements. The potential for collisions between dugongs and vessels is considered slight given that vessels will not be moving through known dugong feeding areas. Movement of vessels other than vessels with limited manoeuvrability (for example, tankers) will be conducted in accordance with the requirements of the EPBC Act and Regulations regarding vessel maintenance and avoidance of marine mammals.

Dredging and Dredge Spoil Disposal: Dredging and dredge spoil disposal operations within Mermaid Sound and beyond DPA limits have the potential to affect marine fauna, benthic primary producers, benthic primary producer habitats, water quality and sediment characteristics.

A detailed Dredging and Dredge Spoil Disposal Management Plan will be developed which will outline specific mitigation and monitoring measures to limit environmental impacts. The plan will be implemented prior to commencement of dredging activities. Mitigation measures will be included for the protection of marine mammals and sea turtles in relation to dredging and dredge spoil disposal activities.

The Dredging and Dredge Spoil Disposal Management Plan will be supported by a suite of monitoring programmes including a baseline pre-dredge study on sedimentation and coral health, predictive forecast modelling, monitoring of physical and biological indicators and a post-dredge baseline study of coral health. The results of the post-dredge survey will be compared to the baseline survey results.

Potential Introduction of Marine Pest Species into Nearshore Waters: Although unlikely, there is a remote potential for marine invasive species to be introduced into nearshore waters (Dampier Archipelago) via LNG and condensate export tankers, discharged ballast water or through residual sediment on dredges or in ballast tanks.

Mitigation measures will include development and implementation of a Marine Pest Management Plan. The *Quarantine Act 1908* (Cwth) and Quarantine Regulations 2000 will be applied and the AQIS ballast water management requirements for international shipping (July 2001) will be compulsory for all vessels entering or leaving Australian waters. Where the potential risk is considered to be high, one or more options for management of ballast water will be implemented, such as no discharge of 'high risk' ballast tanks in Australian waters or tank-to-tank transfers. Construction/installation vessels, including dredges, that come from an overseas last port of call will be inspected prior to arriving on site.

Reduction in Offshore Water Quality Resulting from Hydrotest Discharges: The hydrotesting of the trunkline will result in a waste water discharge stream which will contain residual chemicals. Chemical additives will be selected taking into consideration the best available environmental and technical solutions. The concentrations of the chemical additives in hydrotest fluids will be carefully determined to avoid excess use of chemicals.

A Pipeline Flooding and Hydrotesting Procedure and a Pipeline Pre-commissioning Procedure will be developed. Prior to its implementation, an environmental plan covering flooding, hydrotesting and pre-commissioning activities will be submitted to the relevant regulatory authority for review and approval.

Reduction in Nearshore Water Quality Resulting from the Discharge of Treated Waste Water: Treated waste water comprising produced water (that is, formation water and condensed water), sewage and grey water, non routine contaminated water, accidentally oily contaminated water (AOC water) and demineralised water will be discharged over the life of the Development. These waste water streams will be treated and combined into one treated waste water stream, which will be discharged via a diffuser into Mermaid Sound, seaward of and adjacent to the export jetty.

Management of treated waste water will be in accordance with a Waste Water Management Plan and will include the following measures:

- The residual total hydrocarbon in water concentration of waste water discharged will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound.
- Pluto treated waste water composition will be determined and Whole Effluent Toxicity (WET) testing will be undertaken as soon as first water becomes available and periodically thereafter. Routine monitoring will be conducted to ensure discharged treated waste water meets specified criteria.
- Monitoring of treated waste water will occur at source prior to commingling and at the discharge point. Waste water will be monitored in accordance with regulatory requirements.
- A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms – this will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary.

– Monitoring will confirm that a high level of ecological protection is being achieved at the edge of the agreed mixing zone. The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily.

Although discharge of treated waste water to Mermaid Sound forms the reference case, alternatives are being investigated. Produced water has traditionally been considered a waste product of hydrocarbon production; however, given the scarcity of fresh water in the Pilbara region, options to re-use water are preferred by Woodside over disposal to sea. Potential treated waste water re-use options which are currently being investigated include use within the gas processing plant for service water, use within the NWSV Karratha Gas Plant for service water or use by external parties for non-potable uses (for example, dust suppression).

Hydrocarbon Spills: The risk of an accidental large hydrocarbon spill occurring is highly unlikely and a range of preventative, management and spill response measures will be in place to ensure that a large spill is avoided. An Oil Spill Contingency Plan (OSCP) will be developed and implemented which will:

- ensure effective and timely management of spills of hydrocarbons
- describe the procedures to deal with an oil spill
- define the roles, responsibilities of response personnel
- describe the external resources available for use in combating oil spills and how these resources will be coordinated
- integrate with existing state government, Commonwealth government and industry response plans
- be assessed by DoIR under the P(SL)A which must be approved prior to commencement of operations.

Should any hydrocarbon spills occur within DPA waters, the existing DPA OSCP will apply. The Woodside regional OSCP or a dedicated Pluto LNG Development OSCP will tie into the DPA OSCP for any responses within DPA waters.

Marine Blasting During Construction: Marine blasting will be needed to allow construction of a suitably deep trench for offshore trunkline stabilisation and protection, and to construct the trunkline shore crossing. Mitigation measures to reduce impacts from blasting on marine fauna will be outlined in a Blasting Management Plan, and procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence.

Terrestrial Impacts and Management

The key terrestrial environmental impacts are summarised in **Table ES-1**, along with associated preventative and management measures.

To address higher priority impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to an acceptable level. Key mitigation and management measures for potential terrestrial impacts are summarised in the following section:

Alteration of Natural Drainage Lines within Site B: The layout of the gas processing plant at Site B has been designed to avoid disturbance to significant drainage features and gullies that transect the site. However, a prominent drainage gully will be traversed by two bridges which will link the processing plant located at the centre and south-western area of the site to the associated facilities located on the east of the site, and this has the potential to alter natural drainage within this gully.

Engineering design will be undertaken to minimise interference with surface hydrology flows through the gully, particularly during rainstorm events and cyclones. Various management plans will be developed and implemented including a Groundwater and Surface Water Protection Plan, an Erosion and Sediment Control Plan, and a Weed Management Plan.

Vegetation and Flora Clearing: Approximately 83 ha of vegetation as mapped by Trudgen (2002) will be cleared by earthworks at Site B and Site A. Within Site B and Site A, 21 vegetation associations considered to be of conservation significance by Trudgen (2002) will be cleared to some extent. The proposed clearing requirements will not have a significant impact on the distribution of most of the vegetation communities as generally less then 20% of a vegetation association's regional extent will be removed.

A Vegetation and Flora Management Plan will be developed in consultation with the Department of Environment and Conservation and implemented for the duration of site preparation and construction activities. The plan will address all identified potential vegetation and flora risks and will include measures to minimise impacts on vegetation communities of conservation significance, Priority flora and disturbance to vegetation, flora and habitats in general. The plan will include procedures to ensure the working area is clearly delineated on drawings and on the ground to ensure only the minimum area of vegetation is cleared. A Rehabilitation Management Plan will also be developed and implemented. Much of Site A outside the designated disturbance footprint will not be disturbed (**Figure ES-7**).

Introduction or Spread of Weeds: Introduction or spread of weeds may result from the movement of vehicles, plant and construction materials and from the construction of access routes, clearing of native vegetation and earthworks.

The risk of the introduction and spread of weeds will be minimised through the implementation of a Weed Management Plan. This plan will specify appropriate monitoring, hygiene and weed control measures.

Disturbance to or Loss of Fauna and Fauna Habitat: The disturbance to or loss of fauna habitat within the Pluto LNG Development area will be minimised by ensuring that vegetation clearing and vehicle/personnel movements are restricted to defined disturbance areas. This will minimise the area of habitat that is permanently lost. A Terrestrial Fauna Management Plan will be developed and implemented, and will include procedures to ensure that fauna habitat disturbance is minimised.

The only fauna species of significance which is known to occur within the Development area is the Pilbara olive python. The Pilbara olive python is listed as Vulnerable under the EPBC Act and rare (Schedule 1) under the *Wildlife Conservation Act 1950* (WA), and has been recorded throughout the Burrup Peninsula as well as other areas within the Pilbara region. Surveys and relocation of the Pilbara olive python will be undertaken by trained snake handlers, and snakes will be released in consultation with the Department of Environment and Conservation.

Other species protected under the EPBC Act and the *Wildlife Conservation Act 1950* (WA) that have been identified as potentially occurring within the Development area have either not been recorded recently on the Burrup Peninsula, such as the western pebble mound mouse (*Pseudomys chapmani*) and northern quoll (*Dasyurus hallucatus*), or are highly mobile species with a wide distribution, such as the peregrine falcon (*Falco peregrinus*) and bush stone-curlew (*Burhinus grallarius*).

The beach adjacent to Holden Point at Site A has low flatback turtle and green turtle nesting activity. The beach is not considered to be an important local or regional nesting beach due to its small size and low nesting activity. The beach at Holden Point, will be monitored during the 2006 sea turtle nesting season and additional management strategies will be developed if required in consultation with the Department of the Environment and Heritage and Department of Environment and Conservation.

Fauna species that are not currently protected under legislation but will be potentially impacted by the Pluto LNG Development include short range terrestrial land snails, including *Rhagada* species. A Fauna Management Plan will be prepared and implemented as part of Woodside's commitment to provide guidance for the management of all fauna species during construction.

Soil and Groundwater Contamination due to Small Chemical or Hydrocarbon Spills: Fuel and other hazardous materials required will be stored and used on site; storage of chemicals or hydrocarbons means there is potential for spills to occur.

Good housekeeping will be undertaken to ensure correct storage of hazardous materials. Specific management measures and controls will be developed and incorporated into Waste Management Plans which will include measures to minimise the occurrence of spills, and an Onshore Spill Response Plan will also be implemented.

Noise Impacts from Flaring During Gas Processing Plant Commissioning: At Site B, flaring will occur continuously during the commissioning period for up to six months. However, during operations flaring will be intermittent and will occur primarily during maintenance, shutdown and during upset conditions. During the Front End Engineering and Design phase, consideration will be given to noise reduction measures.

Direct Disturbance to Fauna During Blasting Activities: Blasting will be required during construction in order to prepare level foundations for the Pluto LNG Development infrastructure and facilities. The major impacts from blasting are associated with the generation of dust, noise and vibration, and may cause fauna to temporarily move away from areas.

Impacts from blasting will be managed through the development and implementation of a Dust Management Plan, a Noise Management Plan, a Traffic Management Plan and a Blasting Management Plan. A Sea Turtle Management Plan will be developed and implemented to manage potential impacts to sea turtles during construction of the trunkline shore crossing, jetty and causeway at Site A.

Combustion Products: Combustion products come from the combustion of natural gas in the gas turbines and from flaring events associated with the gas processing plant. The key air pollutants for existing sources of combustion products on the Burrup Peninsula and from the proposed Pluto LNG Development in relation to ambient air quality are: nitrogen dioxide (NO_2), ozone (O_3) and Particulate Matter (PM_{10}).

Management of combustion products from the gas processing plant will be undertaken through implementation of the best available modern LNG processing technologies. The flare design specifications will be such that production of carbon monoxide (CO), oxides of nitrogen (NO_x) and Particulate Matter are minimised. Management of emissions and discharges expected during commissioning and operation will be further assessed and detailed through the Part V (EP Act) regulatory process in the form of a works approval and operating licence which will require government approval prior to commissioning/operation commencing.

Dark Smoke: Dark smoke is caused by the release of soot particles during flaring. Soot particles occur during incomplete combustion when the flare is too cool or there is insufficient oxygen in the flame. The darkness of smoke depends on the amount of carbon particles per volume of gas.

The gas processing plant will not produce dark smoke under normal routine operating conditions. As such there is only a very low risk of impact on ambient air quality from dark smoke.

Social and Economic Impacts and Management

Key social and economic impacts are summarised in **Table ES-1**, along with associated preventative and management measures.

The impact assessment concluded that a number of positive impacts will be generated during the life of the Development. Some of these include:

- peak direct construction employment of up to 3000 people, with up to 200 long-term jobs during operations
- opportunity for Indigenous participation of business development and training programmes
- contribution of A$28.6 billion to Western Australia's Gross State Product and A$17.6 billion to Australia's Gross Domestic Product, based on a two train development over the life of the development
- increased opportunity for local economic activity
- creation of training and business opportunities.

To address higher priority impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to acceptable levels. Key mitigation and management measures for key social and economic impacts are summarised in the following section:

Impacts to Aboriginal Heritage due to Clearing and Earthworks: Regional impacts are considered to be minimal with the total number of engravings within the Pluto LNG Development area representing only a very small fraction of 1% of the estimated number of engravings in the Dampier Rock Art Precinct. An even smaller percentage of rock art lies within the Pluto LNG Development disturbance footprint.

At a local level, detailed archaeological and ethnographic heritage surveys have been completed within Site A and Site B and Woodside has considered these results and the views of the Indigenous groups when designing the disturbance footprint in order to minimise impacts on the cultural heritage landscape (**Figure ES-8a-e**).

Woodside's objective is to leave heritage sites in-situ wherever practicable. Woodside has taken active steps to reduce the impacts of the Pluto LNG Development on Aboriginal cultural heritage and as a result, it is estimated that 5% of rock art identified during the archaeological heritage surveys within Site A and Site B lie within the Pluto LNG Development disturbance footprint. It is Woodside's intention to retrieve and relocate all of the rock art that lies within the Pluto LNG Development disturbance footprint.

Detailed Cultural Heritage Management Plan(s) (CHMP) will be prepared and implemented for the Pluto LNG Development. Measures that will be implemented as part of the CHMP(s) will include but not be limited to the following:

- Heritage sites will be left in-situ wherever practicable. Woodside aims to retrieve and relocate the small proportion of rock art that lies within the disturbance footprint.
- Any proposed disturbance to cultural heritage sites will be subject to an application under Section 18 of the *Aboriginal Heritage Act 1972*.
- Aboriginal sites near work areas will be managed to prevent avoidable impact.
- A cultural heritage induction will be included within the Pluto LNG Development site access inductions.
- Initial site preparation works will be monitored by Aboriginal representatives and expert archaeologists.

Much of Site A outside the designated disturbance footprint will remain undisturbed in accordance with the Ministerial Decision granted under the Aboriginal Heritage Act (**Figure ES-7**).

Impacts to Rock Art from Atmospheric Emissions: The DoIR has appointed the Burrup Rock Art Monitoring Management Committee to assess whether there has been any change to the petroglyphs over and above that due to natural weathering. The Committee has commissioned CSIRO Atmospheric Research to conduct an air pollution monitoring programme to investigate physical, chemical and mineralogical changes in rock surfaces. The first annual measurements of colour change and spectral mineralogy indicate that there is no evidence of colour change or mineralogical change in petroglyphs (Murray 2006).

Effects on the Road Network: Temporary road closures during transport of modular components during the construction phase may include road closures on the MOF Road, NWSV Haul Road and Burrup Road. There may also be increased volumes of traffic on the local road network primarily due to workforce travelling to site during the construction phase. A Traffic Management Plan will be developed and implemented which will:

- identify existing traffic volumes on the public road network
- determine the traffic flow as a result of construction activities
- identify construction periods which will result in less impact on existing public road network traffic.

Spatial Restrictions and Navigational Hazards to Marine Traffic: Loss of access to the area due to permanent exclusion zones around the jetty at Holden Point and navigational hazards presented by construction vessels within Mermaid Sound may impact on marine traffic.

Safety equipment such as markers, navigation aids and illumination lighting will be installed on the offshore platform. Lights and markers will adhere to the internationally recognised International Association of Lighthouse Authorities (IALA) standards.

Impacts on Visual Amenity: The introduction of 'man-made' elements to Site B and Site A will impact upon visual amenity within these sites and the immediate surrounding landscape. There is potential for visual impacts on business and industrial premises, the road network and rights-of-way, footpaths, four-wheel drive tracks, recreational facilities, beaches, ocean and reserves as a result of development of Site B and Site A.

During Front End Engineering and Design the digital terrain elevation model will be used to simulate the 'as-built' design specifications for facilities at Site A and Site B. The results of the additional modelling will be used to determine the requirement for landscaping mitigation measures.

Reduction in Commercial Fishing Grounds: Fishing grounds of three commercial fisheries may be impacted due to exclusion zones or risk of snagging trawl equipment on the trunkline. The fisheries potentially affected are the Pilbara Fish Trawl (Interim)

Managed Fishery, the Onslow Prawn Managed Fishery and the Nickol Bay Prawn Fishery. Restricted areas will be very small in relation to total fishing grounds.

Exclusion zones around platform and sub sea installations will be gazetted and marked on admiralty charts to reduce likelihood of collisions with the offshore platform and/or snagging of trawl gear on sub-sea installations. An exclusion zone will be established around the export jetty. Information relating to the location of permanent Pluto LNG Development components will be provided to the relevant authorities for representation on admiralty charts.

Disturbance to Recreational Activities within Dampier Archipelago During Dredging and Dredge Spoil Disposal Activities: The installation of the offshore trunkline through Mermaid Sound has the potential to cause temporary disruption to recreational diving and boating through elevated Total Suspended Solids (TSS) concentrations within the water column. Similarly, dredging of the navigation channel and disposal of spoil at spoil ground A/B, its northern extension and into deep water site 2B may potentially disrupt these types of recreational activities for approximately 24 months.

A detailed Dredging and Spoil Disposal Management Plan (DSDMP) will be developed and implemented to minimise effects such as elevated TSS concentrations; this will in turn minimise impacts on recreation.

Health, Safety and Environmental Management System

Preventative and management measures will be applied throughout the Pluto LNG Development construction and operational phases, to ensure that all significant environmental impacts associated with the proposed Development are minimised, mitigated or avoided. Various tools will be implemented to ensure sound environmental management. These include an Environment, Health and Safety Policy, preparation of hazard registers, audits of environmental performance, environmental management and performance in tendering and contract requirements, inductions and development and implementation of Environmental Management Plans.

Part of project planning will be ongoing development of the register of environmental hazards to further identify environmental issues, enabling project management to ensure issues are addressed, along with other business priorities in the early screening and design stages. Progress will continue to be periodically reviewed and documentation updated during project design and execution.

Figure ES-8a Initial Site A Design in Relation to Aboriginal Heritage Sites

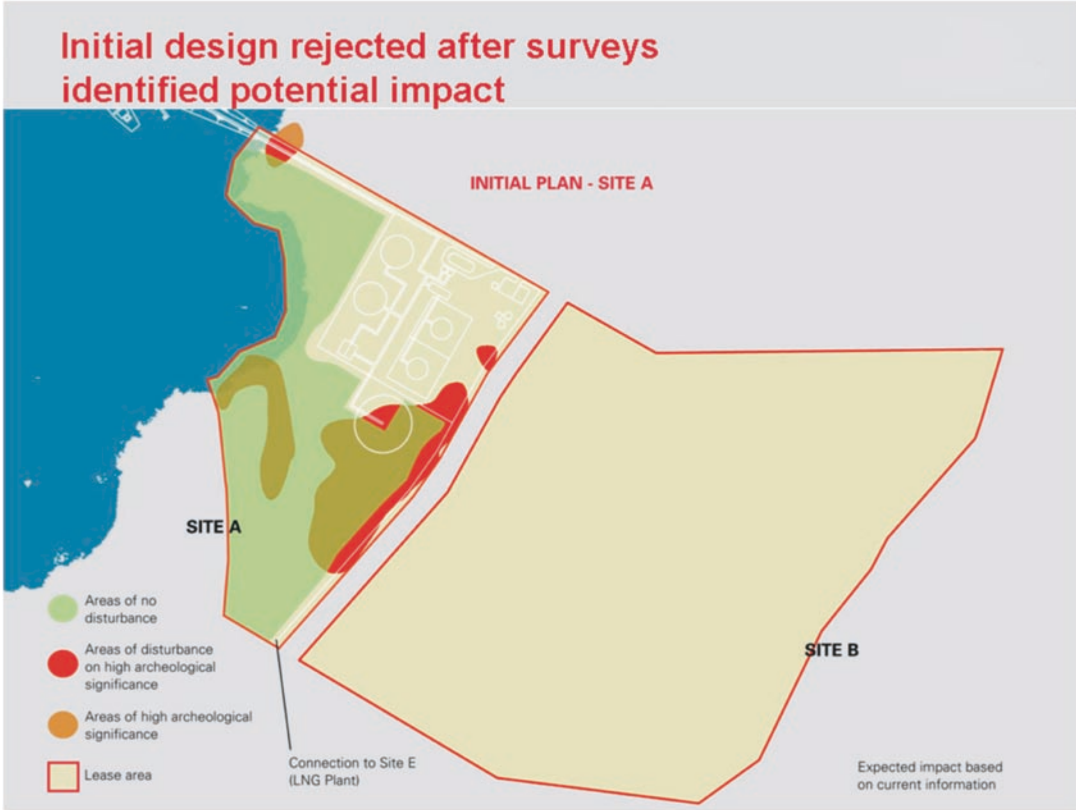


Figure ES-8b Revised Site A Design in Relation to Aboriginal Heritage Sites

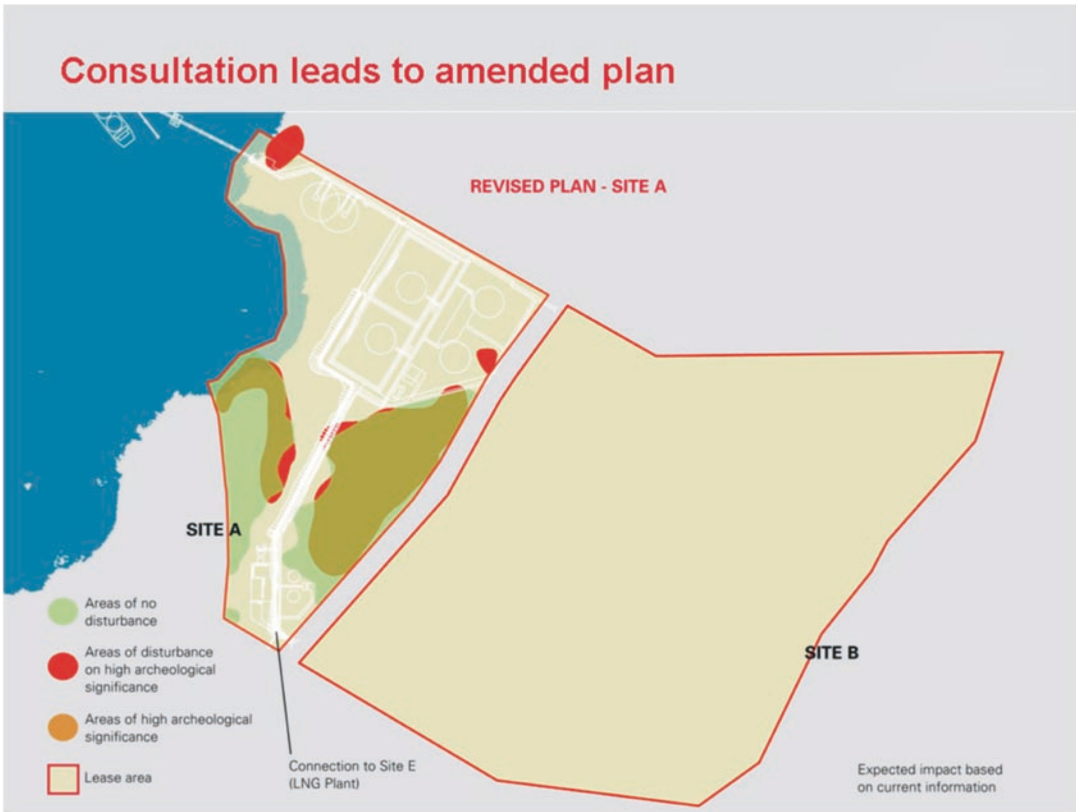


Figure ES-8c Final Site A Design and Initial Site B Design in Relation to Aboriginal Heritage Sites

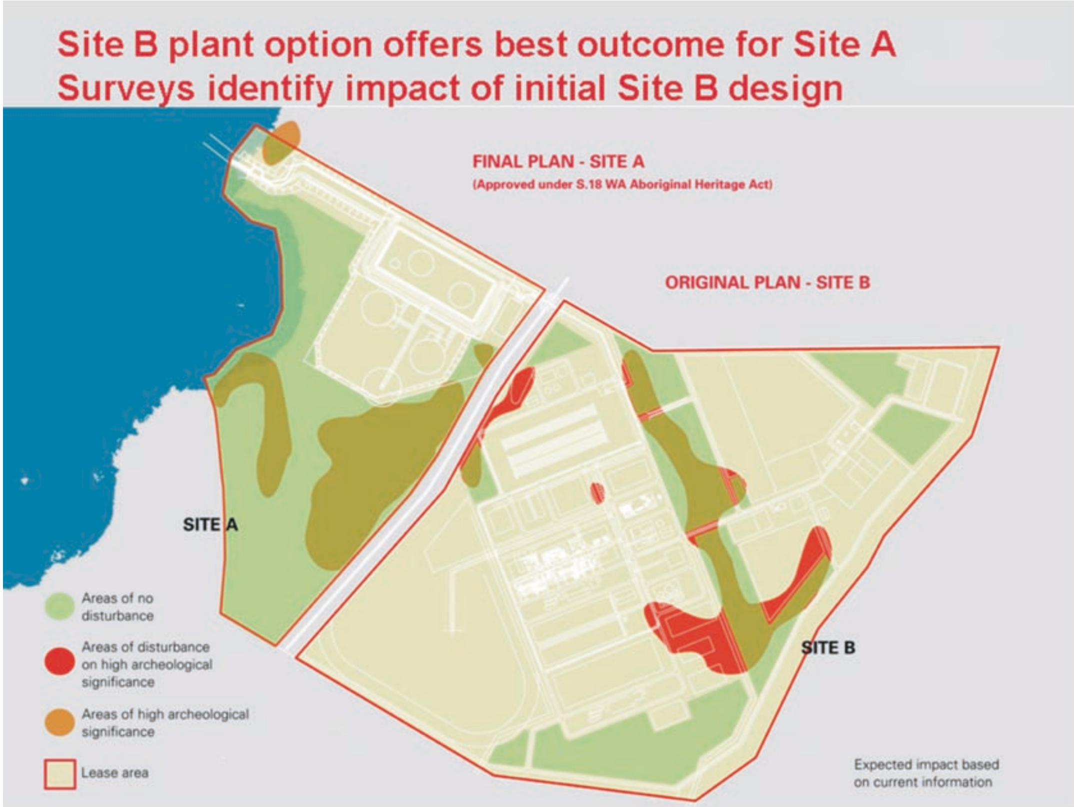


Figure ES-8d Final Site A Design and Revised Site B Design in Relation to Aboriginal Heritage Sites

Figure ES-8e Final Site A Design and Proposed Site B Design in Relation to Aboriginal Heritage Sites

Table ES-1 Table of Environmental Factors

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Terrestrial Environment					
Erosion and Runoff	To maintain the integrity, ecological functions and environmental values of landforms and soils. To minimise the potential for displacement of flood waters and erosion due to storm water flows.	The majority of the Pluto LNG Development is characterised by red shallow sands over a fractured bedrock base with the following exceptions: • Site A has some alluvial deposits, and a sandy beach consisting of calcareous deep sands. • Site B consists mainly of alluvial deposits and numerous small rock piles. The site ranges from 30 m to 80 m in elevation and includes steeply sided channels. The erosion potential of soils is largely determined by slope.	Increased run-off leading to erosion of soil and deposition Creation of unstable soil surfaces/slopes Formation of erosion features such as gullies and rills Soil deposition down gradient of earthworks Adverse changes to surface water quality from elevated levels of silt and suspended materials	Prepare and implement an Erosion and Sediment Control Management Plan which will ensure: • The total area to be disturbed will be restricted to the minimum area required for the Development. • Runoff control measures will be implemented. • Sediment/silt fences will be installed to trap sediment runoff downstream of construction areas. • Erosion and sediment control structures will be routinely inspected and maintained to ensure they remain effective, including the removal of accumulated silt as required. • Areas susceptible to slope instability will be stabilised.	Low residual risk.
Soils	To maintain the integrity, ecological functions and environmental values of landforms and soils.	The Burrup Peninsula is part of a spine of Archaean igneous rocks that includes granophyres, gabbros and small granite exposures. The three principal geological units of the Burrup Peninsula are: • Gidley Granophyre • colluvium (comprising a mixture of boulders, cobbles and gravel) • alluvium (comprising silts and sands). A preliminary desktop assessment indicates that areas of potential Acid Sulphate Soils (ASS) occur within the beach and dune systems of Site A, which are within the disturbance area. No areas of ASS have been identified at Site B. There is little information regarding ASS, groundwater or geotechnical characteristics of the onshore gas trunkline, therefore risk is assumed to be moderate.	Increased surface water runoff due to creation of hard stand surfaces Decreased soil moisture potential Decreased vegetation cover Soil acidification Adverse changes to surface water and groundwater quality Loss of vegetation communities, fauna habitat and flora/fauna biodiversity	Prepare and implement an Erosion and Sediment Control Management Plan which will ensure: • The total area to be disturbed will be restricted to the minimum area required for the Development. • Movement of vehicles will be restricted to designated roads/tracks, and will adhere to onsite speed limits. • Prepare and implement a Groundwater and Surface Water Protection Management Plan. • Should detailed geotechnical investigations and further desktop assessment indicate that ASS are likely to be present within the Development area, a site investigation will be conducted to consider the specific location or locations of disturbance; the nature of disturbance; volume of material to be disturbed and maximum depth of disturbance. .	Soil compaction has been determined as having a low residual risk. There is a low risk of ASS disturbance. The residual risks associated with soil contamination are considered to be low.

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Groundwater	To maintain the quantity and quality of surface and ground water to ensure that existing and potential environmental values, including ecosystems function, are protected.	The soils and bedrock of the Burrup Peninsula are highly permeable and allow the recharge of groundwater during rainfall events; however, the presence of granophyre at shallow depths prevents the potential for long-term subsurface water storage. Geotechnical boring undertaken at a number of locations across Site B did not encounter any groundwater aquifers within approximately 20 m of the surface (Dames and Moore 1998a). Geotechnical site investigations undertaken in 1998 indicated that groundwater at Site A, close to Holden Point and in the vicinity of quaternary sediments, occurred at between 0 m and 3 m AHD, and typically at depths deeper than 3 m below the surface (Dames and Moore 1998b). The highly saline nature of the groundwater makes it unsuitable for use.	Alteration of recharge volumes and rates, watertable levels and/or groundwater flow Reduction in groundwater quality	Prepare and implement a Groundwater and Surface Water Protection Management Plan: • Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water. • Strict procedures will be implemented to prevent leaks or spills of hydrocarbons. • Prepare and implement an Onshore Spill Response Plan including ensuring the appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations.	Low residual risk
Surface Waters	To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected.	Surface water flows on the Burrup Peninsula are channelled off steep slopes into drainage lines and numerous gullies. These high rainfall and short duration events are followed by dry periods that stop stream flow and the recharge of deeper waterholes and gorges. There are several deep drainage channels that transect Site B in a north-west to south-east direction. Most of Site A is located on a localised high point in the landscape and no major external catchments drain through the site.	Changes to natural drainage lines Sedimentation of surface water feature Surface water ponding Increased surface water runoff volumes Adverse changes to surface water quality from contaminants in surface runoff from leaks/spills of hydrocarbon products and other chemicals, or from sediment suspension from surface runoff and transport	Prepare and implement a Groundwater and Surface Water Protection Management Plan: • Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water. • Strict storage procedures will be maintained for environmentally hazardous materials. • Measures will be employed to reduce the risk of flooding such as bunding or raising of site elevation. Prepare an Erosion and Sediment Control Management Plan, which will ensure: • Runoff control measures will be implemented. • Stormwater drainage will be installed at all major storm water outlets within Site A and B • Erosion and sediment control structures will be routinely inspected and maintained to ensure they remain effective, including.the removal of accumulated silt as required.	Low residual risk

Vegetation and Flora	To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	A regional survey of the Burrup Peninsula recorded over 200 vegetation associations, many of which occur within the Pluto LNG Development, including 32 vegetation associations that are considered to be of regional conservation significance. On a site-specific scale, the following vegetation and flora were recorded during field surveys: • Site B – Site B was surveyed in two sections. Site B South had five habitats and 26 vegetation associations (Astron 2005b) and Site B North had six habitats and 43 vegetation associations (ENV 2006a). • Site A – seven habitats and 33 vegetation associations (Astron Environmental 2005a) No Declared Rare Flora were found during surveys of the site. One Priority 3 Flora species, *Terminalia supranitifolia*, occurs within the Pluto LNG Development. An additional 16 flora species of conservation interest were recorded within the Pluto LNG Development area.	Decrease in species abundance Fragmentation of vegetation communities Loss or damage of protected flora species within disturbance area, including Priority 3 species *Terminalia supranitifolia* Reduction in area or damage of vegetation associations of conservation significance	Prepare and implement a Terrestrial Vegetation and Flora Management Plan which ensures that: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Vegetation communities of conservation significance in proximity to working areas will be clearly marked and access to these areas will be prohibited. • Access for vehicles and machinery will be along designated access tracks and parking areas. • The Department of Environment and Conservation will be consulted regarding the development of suitable management procedures for Priority flora. Dust control measures will be incorporated into the Dust Management Plan (refer to **Table G-14**). Fire control measures will be incorporated into the Vegetation and Flora Management Plan. A Weed Management Plan will be developed and implemented as per **Table G-13**.	High residual risk
Terrestrial Fauna	To maintain the abundance, diversity, geographic distribution and productivity of fauna species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge. To protect specially protected fauna species consistent with provisions of the EPBC Act and the *Wildlife Conservation Act 1950* (WA)	Desktop searches have indicated that the following species protected under the EPBC Act and *Wildlife Conservation Act 1950* (WA) could be present within Pluto LNG Development area: • northern quoll • Pilbara leaf-nosed bat • Pilbara olive python • peregrine falcon. Other species of conservation interest to DEC, which could be present, include: • little north-western mastiff bat • skink species *Lerista planiventralis maryani* • skink species *Lerista quadrivincula* • Australian bustard • bush stone-curlew • grey falcon • ghost bat • skink species *Notoscincus butleri* • eastern curlew • western pebble-mound mouse • water rat • land snails such as *Rhagada* species .	Loss of fauna habitat including removal of breeding, nesting and foraging habitats Fauna mortality and injury Protected fauna mortality and injury, including the Pilbara olive python (*Liasis olivaceus baroni*) Short-term disturbance/ displacement of species Predation from introduced species	Prepare and implement a Terrestrial Fauna Management Plan. Impacts will be minimised by the following principles: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Traffic is kept to designated tracks and drivers will abide by the allocated speed limit to minimise fauna fatality or injury by moving vehicles. • All domestic animals are prohibited from the Development area. • Measures are in place to protect the Pilbara olive python, including relocation of Pilbara olive pythons found during earthworks by trained handlers.	Medium residual risk

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Weeds	To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.	Four weed species have been identified in the Development area, including: • Kapok was recorded within gas trunkline Option 1, Site B and Site A. • Buffel grass was recorded in Site B and Site A. • Spiked malvastrum was recorded once within gas trunkline Option 1. • Milk thistle was recorded at Site A but was not abundant	Competition with native vegetation for resources such as light and water Degradation of vegetation communities Proliferation of existing introduced species	Prepare and implement a Weed Management Plan which ensures the following: • Identify and assess controllability of existing weed infestations. • Establish and maintain plant, vehicles and equipment hygiene to prevent introduction and transfer of weeds • Monitor weeds during site preparation works/ construction and operations	Medium residual risk
Marine Environment					
Physical Presence	To minimise the impact of physical presence of temporary and permanent facilities and vessels on the marine environment. To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act. To maintain the integrity and stability of the coast, seafloor and tidal creeks. To maintain the integrity of intertidal flows.	Offshore benthic habitats are characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Localised effects on hydrodynamic regime and sediment transport. Subsea structures provide a habitat for marine fouling communities. Interaction with marine fauna	A Decommissioning Plan will be developed, and approval sought from the relevant regulatory authority, to undertake decommissioning of the facilities. A Dredging and Dredge Spoil Disposal Management Plan will be developed and implemented which will include measures to minimise disturbance to marine mammals and sea turtles during dredging and dredge spoil disposal activities. Compliance with EPBC Act regulations regarding marine mammal interactions and avoidance. A Sea Turtle Management Plan will be developed and implemented.	Generally low residual risk; however, risk of interaction with marine fauna is considered medium

Seabed Disturbance	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To maintain the ecological function, abundance, productivity, biodiversity and geographic distribution of mangrove, algal and seagrass communities. To meet the values and objectives outlined in the *Pilbara Coastal Water Quality Outcomes: Environmental Values and Environmental Quality Objectives*.	The seabed throughout the Development area comprises soft sediments, is considered relatively benign and supports a relatively low abundance of benthic biota. The exceptions are areas of sensitivity including areas of coral reef and sponge communities within the Dampier Archipelago.	Localised offshore seabed disturbance Direct disturbance to coral reefs and sponge communities	Routing flowlines and trunkline to avoid areas of sensitivity including rock pinnacles. Barge anchoring procedures will be developed for pipelay activities and will include: • Accurate positioning of anchors to avoid or minimise impact to sensitive areas. • Identification and incorporation of areas of hard substrate including sponge communities and coral reefs into a geo-referenced habitat map. • Prevention of anchor wire drag on the seabed by ensuring sufficient tension is maintained during anchor running operations.	Low residual risk to offshore seabed and to nearshore seabed from rock dumping and impacts on spoil ground. Medium residual risk to benthic communities including corals from trunkline laying and anchoring. High residual risk to sponge communities south-west of Legendre Island and coral reef adjacent to Holden Point, in Mermaid Sound, from construction activities including pipeline laying.
Marine Pest Species	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.	No marine pest species have been identified in the Development area; however some (non-pest) species have been previously introduced into the Dampier Archipelago.	Competition for food and space with native species Predation of native species (including commercial species) Possible hybridisation between native and introduced species	A Marine Pest Management Plan will be developed and implemented. Application of the *Quarantine Act 1908* and Regulations 2000 (Cwth) and the AQIS ballast water management requirements for international shipping (July 2001) will be compulsory for all vessels entering or leaving Australian waters. Where the potential risk is considered to be high, one or more of the following options for management of ballast water will be implemented: • no discharge of 'high risk' ballast tanks in Australian waters • tank-to-tank transfers • full ballast water exchange at sea (that is, beyond 12 nm from the coastline).	Low residual risk from vessels operating in the Pluto gas field. Medium residual risk from vessels operating in the Dampier Archipelago.
Drill Cuttings	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Decrease in water quality through localised increase in turbidity Disturbance to marine flora and fauna Mortality or disturbance to benthic species and habitats Localised alteration of seabed morphology (cuttings piles) Reduction of oxygen transfer to underlying sediments	Control measures detailed in a Drilling Environment Plan (EP) will be developed and approved by the WA DoIR. Drilling will not be undertaken in, or close to, sensitive seabed habitat.	Low residual risk

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Drilling Muds	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Decrease in water quality through localised increase in turbidity Disturbance to marine flora and fauna Increase in sediment oxygen demand Alteration of benthic habitat community structure	Control measures detailed in a drilling Environment Plan (EP) will be developed and accepted by the WA DoIR. NWBMs will only be used where WBMs cannot provide the required specifications (for example, lubricity, bore stability). NWBMs will be re-used and recycled. Transfer of drilling mud between the support vessel and drilling rig will be in accordance with a regulatory accepted EP.	Low residual risk
Sludges and Sands	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Decrease in water quality through localised increase in turbidity Disturbance to marine biota and habitats Build-up of sediments on sea floor Smothering of benthic communities and alteration of sediment particle size Alteration of sediment characteristics	Where practicable, sludges and sand will be minimised at source, by using sand consolidation resins and completion stacks. Sludges and sand will be stored offshore and then transported onshore for treatment or disposal at an approved facility, unless approval can be gained to dispose of material overboard. Disposal overboard will occur if approval is gained from the regulatory authority (either as part of an accepted plan or as a specific approval), and will not occur if sands or sludges are unacceptable for discharge.	Low residual risk
Well Completion and Subsea Fluids	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Impacts on water quality Toxicity to biota	Low toxicity brine solutions selected. Selection of fluids with low toxicity (for example, MEG), subject to meeting operational requirements. Minimal volumes to be used.	Low residual risk

Deck Drainage	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	The North West Shelf generally has very low levels of anthropogenic contamination.	Localised reduction in water quality from contaminated deck drainage	Areas on vessels, drill rigs and the offshore platform where hazardous materials will be stored, including fuels, oils and lubricants, will be bunded, and directed to a sump (or similar) which is connected to an oily water separator. Drainage water with hydrocarbon concentration >15 ppm will be treated to reduce concentrations to below 15 ppm and discharged overboard as per MARPOL73/78 regulations. Remaining hydrocarbons will be stored in suitable containers and transported to shore for treatment and/or disposal by a certified waste oil disposal contractor. If vessels do not have an oily water separator, drainage water will be recovered, stored on board and then shipped to shore for treatment.	Low residual risk
Hydrotest Water	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act. Minimise impacts on sediment and water quality. To meet the values and objectives outlined in the Pilbara Coastal Water Quality Outcomes: Environmental Values and Environmental Quality Objectives.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area. The North West Shelf generally has very low levels of anthropogenic contamination.	Effects on biota and water quality resulting from oxygen deprivation and biocides	A Pipeline Flooding and Hydrotesting Procedure and a Pipeline Pre-commissioning Procedure will be developed. Prior to its implementation, an environmental plan covering flooding, hydrotesting and pre-commissioning activities will be submitted to the regulatory authority for review and approval. Chemicals used as inputs into the hydrotest water will be chosen to ensure that the best environmental and technical solutions are achieved for the Development.	Medium residual risk
Anti-Fouling	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	Previous studies have rarely found contaminants in sediments of the Dampier Archipelago; this is attributable to the lack of riverine inputs and controls on discharges associated with current industrial development. Sediments in Mermaid Sound are considered to be generally clean with Tributyltin (TBT) the only contaminant of concern.	Toxic effects on marine biota	Construction and/or operation vessels to adhere to complete prohibition on the presence of TBT paints on ships by 1 January 2008. Selection of chemicals with the lowest health, safety and environmental risks while meeting technical requirements.	Low residual risk

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Ballast Water	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. Minimise impacts on sediment and water quality.	The North West Shelf generally has very low levels of anthropogenic contamination.	Effects on biota and water quality	Tankers will be of an acceptable standard. Vessels must have dedicated ballast tanks; fuel tanks or other holding areas must not be used to hold ballast water. The use of fully segregated ballast water tanks is a requirement of the vetting process; vessels that do not satisfy this requirement are not permitted. The same standard will be applied to all vessels. All vessels will comply with MARPOL regulations.	Low residual risk
Naturally Occurring Radioactive Material (NORMS)	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. Minimise impacts on sediment and water quality.	The produced water contained within the Pluto reservoirs may contain minimal quantities of Naturally Occurring Radioactive Materials (NORMS).	Toxicity effects on marine flora and fauna	Management and disposal of NORMS in accordance with the APPEA 2002 guidelines 'Guidelines for Naturally Occurring Radioactive Materials, Australian Petroleum Production and Exploration Association Limited, Canberra'. Use of an appropriate scale inhibitor to control build-up of scale (and therefore NORMS). The disposal and management of NORMs at the decommissioning phase will be subject to procedures and practices to be defined within a Decommissioning Plan.	Low residual risk
Cooling Water	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. Minimise impacts on sediment and water quality.	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area.	Reduction in water quality	The use and dosage of biocide in cooling water will be kept to the minimum required to ensure the cooling water system is in suitable condition for operational purposes. Rapid dispersion of the biocide by the surrounding ocean at the discharge point will also assist in minimising impacts.	Low residual risk

Treated Waste Water	To ensure that potential impacts associated with waste water, are managed to ALARP. To minimise impacts on the marine environment. To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. To maintain the ecological function, abundance, productivity, biodiversity and geographic distribution of mangrove, algal and seagrass communities. To minimise impacts on sediment and water quality. To comply with the Environmental values and Environmental Quality	The offshore benthic habitat is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds are known to move through the area, for example annual migration routes of humpback whales intersect the Development area. The North West Shelf generally has very low levels of anthropogenic contamination. Waters in the Dampier Archipelago are considered oligotrophic on occasions, blooms of nitrogen-fixing microbes such as Trichodesmium or mangrove mud-flat cyanobacterium may contribute significant amounts of nutrients into the marine environment. High spatial and seasonal variability are evident in nutrient and chlorophyll concentrations within the Dampier Archipelago.	Pollution and nutrient enrichment of offshore and nearshore waters Toxicity to some species Reduction in water quality Reduction in marine sediment quality	An IMO certified sewage treatment plant, capable of servicing the full complement of crew, will be in place on all construction, operation and decommissioning vessels. Sewage and grey water from contracted vessels will be disposed of in accordance with P(SL)A, MARPOL 73/78 and DPA requirements (within DPA limits). Vessels will not discharge untreated sewage or putrescible waste within 12 nm of land. Food wastes, sewage and grey water from drilling rigs and platforms will be, as a minimum, passed through a grinder or comminuter so that the final product will pass through a screen <25 mm diameter prior to disposal to the sea at a distance greater than 3 nm from land (as per P(SL)A requirements). Prior to discharge into port waters from an IMO approved sewage treatment plant onboard a vessel, the DPA will be provided recent laboratory results to confirm the sewage treatment plant is operating effectively. Management of treated waste water including produced water, will be in accordance with a Waste Water Management Plan and will include the following principles: • Pluto waste water composition will be determined and Whole Effluent Toxicity (WET) testing will be undertaken as soon as first water becomes available and periodically thereafter. Routine monitoring to ensure discharged waste water meets specified criteria. • A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities, and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary. • Reporting procedures consistent with regulatory, local and Development requirements will be developed. • A contingency plan will be developed to manage waste water in cases where unexpected volumes and/or quality of waste water are produced.	Risk of impacts from sewage and grey water generated offshore, and by vessels is considered low. Risk of impacts to water quality from discharge of treated waste water, including produced water, into Mermaid Sound is considered high. Risks to marine sediment quality and protected areas are considered low.
Dredging and Spoil Disposal	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act.	Waters of the inner Archipelago experience naturally higher levels of turbidity as a result of local re-suspension of fine sediments caused by wind and tidal mixing, with levels being highly site dependant. High levels of natural turbidity also occur during and after cyclones and rainfall events as a result of wave action and run-off. Natural sedimentation levels as high as 240 mg/cm2/d averaged over five consecutive days (highest single value was 330 mg/cm2/d) have been observed in Mermaid Sound without any corresponding coral impact (IRCE 2004a).and are likely to reach even higher levels as a result of cyclones and possibly during dredging activities.	Direct removal of benthic primary producer habitat. Increase in TSS and associated light attenuation in areas of benthic primary producer habitat, sponge communities and other benthic biota Effects on EPBC Act listed species, habitats and foraging areas (including sea turtle and dugong habitat in Dampier Archipelago)	A detailed Dredging and Dredge Spoil Disposal Management Plan will be developed and implemented. This plan will be submitted to the DEH for approval prior to dredging commencing. Management measures that will be considered include: • Preventing dredging operations during coral mass spawning events in areas where activity may adversely affect corals or coral larvae settlement. • Reducing impacts associated with propeller wash, as far as reasonably practicable by targeting dredging of shallow areas to times when the dredge vessel is empty and/or coincide with high tide. • Utilising favourable weather, tide and current conditions as far as reasonably practicable to limit effects when dredging or disposal in close proximity to sensitive areas	• High residual risk to Benthic Primary Producer Habitat • Medium residual risk to sponge community assemblages and other benthic biota from light attenuation and smothering in Dampier Archipelago. • Medium residual risk to benthic biota from light attenuation and smothering at deep water spoil grounds.

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
	To maintain the ecological function, abundance, productivity, biodiversity and geographic distribution of mangrove, algal and seagrass communities. Minimise impacts on sediment and water quality.		Smothering effects leading to stress and mortality of benthic primary producer habitats, sponge communities and other benthic habitats TBT effects to marine biota Alteration of surrounding sediment characteristics. Reduction in water quality in Mermaid Sound. Mechanical impact of anchors and anchor line drag on corals.	• Reducing trailer suction hopper dredge overflow and overflow of barges through operational procedures. • The use of sea turtle deflection devices will be considered for use on trailer suction hopper dredges. These devices are not considered feasible for application to cutter suction dredges. Alternatives to turtle deflectors will also be considered. • Prior to commencement of dredging activities, the dredging contractor and crew will receive induction that, among other things, describes the location of sensitive marine mammal and sea turtle habitat in relation to proposed dredging activities and seasonal environmental sensitivities, such as the humpback whale migration and coral spawning events. • Procedures for protection of marine mammals and sea turtles (e.g. visual monitoring) during dredging and spoil dumping. The Dredging and Dredge Spoil Management Plan will be supported by a suite of monitoring programmes including a baseline pre-dredge study on sedimentation and coral health, predictive forecast modelling, monitoring of physical and biological indicators and a post-dredge baseline study of coral health.	• Low residual risk from disturbance to marine fauna and TBT contamination. • Low residual risk to marine mammals and sea turtles.
Hydrocarbon Spills	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950 (WA) and the EPBC Act. To maintain the ecological function, abundance, productivity, biodiversity and geographic distribution of mangrove, algal and seagrass communities. Minimise impacts on sediment and water quality. To ensure hydrocarbons and hazardous materials, are handled and stored in a manner that minimises the potential impact on the environment through leaks, spills and emergency situations.	The offshore environment is characterised by generally soft sediments supporting sparse but highly diverse infaunal and epifaunal communities. Marine mammals and seabirds migrate through the area of the proposed offshore facilities, including humpback whales.	In the unlikely event of a hydrocarbon spill into the marine environment potential environmental impacts include: • Physical effects – including coating and/or smothering of marine biota leading in certain cases to contamination and mortality • Chemical and biological effects (toxicity and bioavailability) – including sub-lethal and lethal effects on marine biota caused mainly by the water soluble aromatic hydrocarbons (for example, benzenes) and the lower molecular weight polycyclic aromatic hydrocarbons (PAHs).	The likelihood of a large hydrocarbon spill occurring from the Pluto LNG Development is remote. A large number of engineering and procedural measures will be implemented to minimise and avoid potential for hydrocarbon spills. Should a hydrocarbon spill occur within DPA waters, the DPA OSCP will apply. The Woodside Regional OSCP or Pluto LNG Development OSCP will tie into the DPA OSCP for responses within DPA waters. In the unlikely event of a hydrocarbon spill that is beyond the response capability of Woodside, a request will be made for the activation of the State Plan or National Plan to 'Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances' (or within DPA limits, the DPA Plan). Support for oil spill response and management is available from other oil and gas operators in the region under a Mutual Aid Agreement and within 24 hours of notification from the industry sponsored Australian Marine Oil Spill Centre (AMOSC) based in Victoria.	Low to medium residual risk

Social Surroundings					
Aboriginal Heritage Sites	To ensure that the proposal complies with the requirements of the *Aboriginal Heritage Act 1972* (WA). To minimise impacts to heritage sites and adopt a best practice heritage management approach through the Development and implementation of a Cultural Heritage Management Plan(s) in consultation with Indigenous groups and relevant experts.	It has been estimated that the Dampier Archipelago may feature well over one million rock art motifs with 17-77 Aboriginal heritage sites per square kilometre occurring on the Burrup Peninsula (Vinnicombe 2002) During the archaeological heritage surveys a total of 80 archaeological heritage sites were recorded at Site A and 129 at Site B. These surveys found that the archaeological sites include 1240 rock art panels (2488 individual motifs) at Site A and 220 rock art panels (356 motifs) at Site B. Site B is approximately twice the size of Site A which indicates that Site B has a relatively sparse distribution of rock art. The majority of rock art is distributed along the eastern and south-western margins of Site A and as expected within rocky hills, intervening valleys and watercourses generally. For technical as well as environmental reasons Woodside is trying to limit the Pluto LNG Development to the flat upland areas of Site A and Site B as far as possible which Woodside expects will result in over 95% of the rock art within Site A and Site B occurring outside of the proposed disturbance footprint. The Burrup Rock Art Monitoring Management Committee has commissioned CSIRO Atmospheric Research to undertake field studies into rock art to investigate physical, chemical and mineralogical changes in rock surfaces. Focus is on determining early indicators of damage to rock art. The first annual measurements indicate there is no clear evidence of colour change or mineralogical change in petroglyphs (Murray 2006).	Disturbance to Aboriginal sites Inappropriate access by the workforce Damage to or loss of heritage sites	Detailed Cultural Heritage Management Plan(s) (CHMP) will be prepared and implemented for the Pluto LNG Development. Measures that will be implemented as part of the CHMP(s) will include but not be limited to: • Heritage sites will be left in-situ wherever practicable. Woodside aims to retrieve and relocate the small proportion of rock art that lies within its disturbance footprint. • Any proposed disturbance to cultural heritage sites will be subject to application under Section 18 of the *Aboriginal Heritage Act 1972* (WA). • Aboriginal sites near work areas will be managed to prevent avoidable impact. • A cultural heritage induction will be included within the Pluto LNG Development site access inductions. • Initial site preparation works will be monitored by Aboriginal representatives and expert archaeologists.	Low to medium residual risk
European Heritage	To ensure that the proposal complies with the requirements of the *Heritage of Western Australia Act 1990* (WA) and Commonwealth requirements.	The nearest registered historical sites to the Pluto LNG Development are: Dampier Fire Station, Kindergarten and Church and the Uniting Church in Dampier, all approximately 7.5 km away from Site A and Site B.	No impacts are predicted	Not considered necessary.	Low residual risk
Land Use and Tenure	To minimise impacts on the commercial uses of the area. To ensure that land-use and tenure is not affected in the area of the development.	The Pluto gas field is located in exploration permit WA-350-P, and is 100% operated by Woodside. Sites B and A are currently vacant and zoned for industrial use under the Burrup Land Use Plan and Management Strategy.	Proposed development is consistent with existing tenure	Not considered necessary.	Low residual risk
Protected Areas	To avoid disturbance to conservation areas and the ecosystems values of these areas including to maintain flora and fauna, habitats and water quality in conservation areas.	Existing terrestrial protected areas in the vicinity include a number of island nature reserves including Dampier Archipelago Nature Reserves, Great Sandy Islands Nature Reserve and the Lowendal Island Nature reserve, located 1.3 km, 20.4 km and 42.2 km away from the Pluto LNG Development respectively.	There will be no impacts upon protected sites	Not considered necessary.	Low residual risk

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Fisheries	To minimise disturbance to fisheries as far as reasonably practicable.	Catches from the Pilbara fisheries dominate the current Western Australian metropolitan markets and support the local fish processing sector, and the export of scale fish to Europe and Asia is also becoming increasingly important. Commercial fishing consisting of prawn and finfish trawling, and finfish trapping and wetlining makes an important contribution to the regional economy. Recreational boating and fishing is a popular activity in the Dampier Archipelago.	Slight potential reduction of fishing grounds of three commercial fisheries Disturbance to recreational fishing during dredging and dredge spoil disposal	Construction corridor for the offshore trunkline will be limited as far as practicable to reduce potential impacts to fish habitat, feeding and spawning areas. Information relating to the location of permanent Development components will be provided to the relevant authorities for representation on admiralty charts. Exclusion zones around platform and subsea installations will be gazetted and marked on admiralty charts to reduce likelihood of collisions with the offshore platform and/or snagging of trawl gear on subsea installations. An exclusion zone will be established around the export jetty.	Low to medium residual risk
Traffic	To ensure site traffic is managed in such a way so as not to adversely impact on community, road users, road infrastructure and sensitive habitats. To minimise dust generation through traffic movements.	Dampier Road and Burrup Road form the main route between Karratha and the Burrup Peninsula. Both of these roads are identified as 'State Roads' and come under the care and control of MRWA. Levels of service on the local road network are generally considered satisfactory to good.	Increased traffic volumes Impacts on traffic due to closures on MOF Road and NWSV Haul Road	Prepare and implement a Traffic Management Plan to ensure: • Emergency access will be provided for at all times. • Identify existing traffic volumes on the public road network. • Determine the traffic flow as a result of construction activities. • Identify construction periods which will result in lessened impact on existing public road network traffic. • Monitor the impact of heavy vehicles on the public road network. • Identify the location of truck lay-up areas to be used outside of their usage periods.	Medium residual risk
Infrastructure	To minimise disturbance to existing infrastructure as far as reasonably practicable.	Air Transport Facilities: There are four major airports in the region, the closest of which is Karratha Airport, 10 km (straight line distance) from Site B. Ports: The Port of Dampier is one of Australia's largest ports by tonnage and facilitates the export of iron ore, salt, LNG, liquid petroleum gas and condensate totalling about 89 mtpa. Water Supply: Two major water supply schemes currently operate in the Pilbara region. Water Corp. also has plans to expand its desalination water supply system it has in place with Burrup Fertilisers Pty Ltd. Communications: Major towns in the Pilbara region have internet connections and access to ISDN, STD, facsimile, telex and data link services. Energy: North West Shelf Gas administers contracts for the sale of gas, including the supply of power stations in the mining areas at Dampier, Cape Lambert, Port Hedland and Newman.	Pressure on existing infrastructure and utilities	Sewage treatment and disposal facilities will be provided during onsite during construction and operation. All operations will be self-sufficient with regards to power generation. A Social Impact Management Plan is being developed.	Low residual risk
Marine Traffic	To minimise impacts on marine traffic during construction and operational phases of the development. To minimise impacts on the commercial uses of the area.	In 2004/2005 there were 2105 trade vessel arrivals and further 564 other vessel arrivals for a total of 2669 arrivals at the Port of Dampier Approximately 2000 vessels travelled through Mermaid Sound to the Dampier Port in the 2004/2005 financial year.	Loss of access to the area and navigational hazards represented by permanent structures and construction vessels within the Pluto gas field, the trunkline route and the Mermaid Sound	A gazetted safety exclusion zone of 500 m radius around the offshore platform and associated structures or equipment. Exclusion zone will appear on Australian navigation charts. Safety equipment such as markers, navigation aids, fog horns and illumination lighting will be installed on the offshore platform.	Low to medium residual risk

Tourism and Recreation	To minimise potential impacts on recreational uses of the area.	To the south of Holden Point and bordering Site A to the west, there is a sandy bay and beach which is used for recreational purposes, however, public road access to the beach is prohibited and access is therefore only possible by boat. Recreational activities are popular in and around the Dampier Archipelago including diving, swimming and boating.	Restriction of access to beach west of Site A and/or impacts on visitors from blasting and other construction activities As a result of elevated turbidity associated with dredging and spoil disposal, there is potential for temporary impact on water-based activities	Measures that will be implemented to reduce potential impacts on existing recreational user groups include the installation of warning signs. An observer will also monitor the beach from a safe location (either on the beach or a nearby boat) to prevent boats landing or to stop blasting until the beach has been cleared Development and implementation of a Dredging Spoil and Disposal Management Plan.	Low to medium residual risk
Visual Amenity	To minimise impacts on the visual amenity of the area adjacent to the project.	The following landscape character types were identified within the southern extent of the Burrup Peninsula: • industrial complexes • tidal flats, inlet and saline flats • high scree slopes and rock outcrops • naturally regenerated grassland steppes • grassland steppes • valleys and incised drainage lines. There are no residential properties within 2 km of Site A and Site B or the proposed onshore trunkline route.	Some reduction in visual amenity and aesthetics of the local area, including the wider Burrup Peninsula	During the Front End Engineering and Design phase the digital terrain elevation model will be used again to simulate the 'as built' design specifications for facilities at Site A and Site B	Medium to high residual risk
Economic Environment	To support the local, regional and national economy.	The Western Australian economy is currently being strongly driven by a resources boom. A large portion of the business investments have been made in the Pilbara region.	Peak direct construction employment of up to 3000 people, with up to 200 long-term jobs during operations. Opportunity for Indigenous participation of business development and training programmes. The contribution of $17.6 billion to Australia's Gross Domestic Product and $28.6 billion to Western Australia's Gross State Product, based on a two train development over the life of the Development. Increased opportunity for local economic activity. Creation of training and business opportunities.	A Social Impact Management Plan is currently being developed.	Risk rating is not applicable to positive impacts.
Military Zones	To minimise disturbance to military zones.	The Pluto gas field falls within the Western Australian Exercise Area (WAXA).	Conflict between service aircraft and military aircraft	Consultation with the Commonwealth Department of Defence to discuss potential conflicts and to identify suitable management measures, if required.	Low residual risk

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Social Environment	To investigate and manage potential adverse social issues appropriately.	The proposed Pluto LNG Development will be located on the Burrup Peninsula within the Shire of Roebourne. Towns in the Shire include Karratha, Dampier and Wickham. Indigenous groups in the Shire include the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo. Site B and A are situated approximately 17 km and 14.5 km from Karratha, and 8 km and 7.5 km from Dampier respectively. Karratha, in 2001, had a population of 10 776 with a median age of 30. Dampier had a population of 1490 in 2001 with a median age of 34.	Based on initial reviews, consultation and desktop studies, initial significant social impacts that have been identified include (but are not limited to) the following broad categories: • housing and land availability, including design and location • employment, education and training • workforce management • local, state and Commonwealth economic activity • community development and essential service availability.	A Social Impact Management Plan is being developed.	Low residual risk
Pollution Management (Terrestrial and Marine)					
Non-Hazardous Waste Stream	To ensure that potential impacts associated with liquid and solid wastes, are managed to ALARP. Minimise impacts on soils, surface and ground water.	There are currently no existing sources of solid waste from the Pluto LNG Development.	Attraction of pest species Generation of odours Reduction in marine water quality	Food waste from vessels will be macerated and discharged to the marine environment when outside of the 12 nm zone. Within that zone food waste will either be disposed of in general waste bins, which will be transferred onshore for disposal, or macerated and held in tanks until the vessel is beyond the 12 nm boundary. No other solid wastes will be discharged to the marine environment. Food wastes, sewage and grey water from drilling rigs and platforms will be, as a minimum, passed through a grinder or comminuter so that the final product will pass through a screen <25 mm diameter prior to disposal to the sea at a distance greater than 3 nm from land. Prepare and implement a Waste Management Plan which will require that: • Recycling bins will be located in strategic locations around site to facilitate segregation of waste, diverting recyclable solid waste streams from landfill. • All domestic waste will be stored in clearly marked skips and waste containers will be provided through out construction and operational sites. • Green waste will be segregated from other waste streams. The material will be mulched and reused on site if practicable. • Contractors will be required to place a high emphasis on housekeeping and all work areas will be required to be maintained in a neat and orderly manner.	Low residual risk

Hazardous Waste Stream	To minimise impacts on existing waste facilities. To minimise environmental impacts associated with waste generation and accidental spills. Maximise waste reduction, recycling, reuse and recovery.	There are currently no existing sources of hazardous waste from the Pluto LNG Development.	Contamination of soil Contamination of groundwater, surface water or the marine environment Adverse impacts on marine biota	Prepare and implement a Waste Management Plan which will require that: • All hazardous waste materials will be documented and tracked, segregated from other waste streams and stored in suitable containers. • All hazardous materials will be handled and stored in accordance with the corresponding MSDS and Australian Standards. An Onshore Spill Response Plan will be implemented and developed to include: • Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations.	Low residual risk
Non-Routine Discharges	To reduce the risk of accidental spills occurring and ensure effective management measures are deployed in the event of a spill. Minimise the potential for water quality reduction and subsequent impacts on marine and terrestrial biota. Minimise impacts on soils, surface and ground water.	There are currently no existing sources of non-routine discharges from the Pluto LNG Development.	Soil contamination Groundwater and surface water contamination Death or injury to fauna	Waste Management Plans will be developed and implemented to include the following: • Hazardous materials storage facilities and handling equipment will be designed and constructed to prevent and contain spills. • Appropriate controls on the AOC water system to enable isolation of spill events to prevent contamination of large volumes of liquid, and facilitating extraction of specific contaminated liquids. A Groundwater and Surface Water Protection Plan will be prepared and implemented, and will incorporate the following: • Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water. • An Onshore Spill Response Plan will be developed and implemented; this will include reference to relevant spill prevention and management procedures.	Low to medium residual risk
Greenhouse Gas Emissions	To minimise greenhouse gas emissions to ALARP.	Atmospheric emissions from the largest existing sources of air pollution on the Burrup Peninsula are associated with the NWSV Karratha Gas Plant, iron ore handling and port activities near Dampier, Hamersley Power Station and Burrup Fertilisers Ammonia Plant.	Incremental increase in global concentration of greenhouse gases	Develop and implement a Greenhouse Gas Management Plan as follows: • Minimising venting and flaring of hydrocarbons and fuel gas consumption by using procedural solutions to reduce venting, flaring and combustion of hydrocarbons to as low as reasonably practicable. • Minimising releases by ensuring equipment is correctly maintained. • The quantities of gaseous emissions offshore are anticipated to be relatively small.	Outputs minimised

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Combustion Products	To ensure that atmospheric emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards. Reduce flaring and combustion of hydrocarbons to as low as reasonably practicable.	Atmospheric emissions on the Burrup Peninsula are associated with iron ore handling and port activities near Dampier, the NWSV Karratha Gas Plant, Hamersley Power Station and Burrup Fertilisers Ammonia Plant. In a review of cumulative NO_x impacts from existing and proposed industries on the Burrup Peninsula, EPA (2004) noted that air quality monitoring in 1999 showed no exceedences of NEPM standards for NO_2, ozone (O_3), and SO_2 at any of the monitoring sites at Dampier, Karratha and King Bay. EPA (2004) concluded that there is no health concern relating to current levels of these air pollutants.	Potential (low risk) ambient air quality impacts primarily from emissions of NO_x reacting with atmospheric gases photochemically and affecting ambient NO_2 and ozone concentrations Potential (low risk) ambient air quality impacts from pollutants other than those caused by NO_x emissions such as benzene, particulate matter etc Potential (low risk) ambient air quality impacts from the components of natural gas	Development and implementation of a Greenhouse Gas Management Plan which will include: • Ensuring Flaring events will be minimised to ALARP. • Combinations of the following technologies have been implemented in the two plant designs: • Dry-low NO_x burners in the process refrigeration and power generation gas turbines. • Waste Heat Recovery Units to be located on one or more compressor gas turbines in each train to reduce the consumption of fuel gas. • An AGRU Thermal oxidiser to destroy sulphurous compounds and hydrocarbons such as BTEX by conversion to CO_2. • Where diesel fuel is required, the use of Australian Standard marine diesel, which is low in sulphur will minimise the generation of SO_x.	Low residual risk
Dark Smoke	To ensure that the effects of dark smoke emissions on the environment and communities are minimised.	Dark smoke can be caused during flaring due to incomplete combustion of products, and is primarily a visual impact. Environmental impacts from dark smoke emitted from a gas processing plant are considered negligible.	Reduction of visual amenity	Maintenance of gas processing plant to ensure efficient flaring. Monitor and record the colour and duration of stack emissions: • during a dark smoke event that continues for greater then a 4- minute period during any one hour period • during gas processing plant startups and shutdowns • in response to any complaints being received regarding dark smoke • engineering design philosophy will be to achieve no routine dark smoke emissions.	Low residual risk
Dust Emissions	To ensure that the effects of dust generation on the environment and communities are minimised.	Sensitive local receptors on the Burrup Peninsula include Hearson Cove, a popular recreational beach, the existing Dampier Port Authority and associated infrastructure to the south (2 km) and south-west (3 km) of sites A and E respectively. The Karratha Gas Plant is located 700 m to the north of Site A and Site B. The nearest residents live in Dampier, approximately 6 km in a straight line south-west of Site A and Site B.	Reduction of visual amenity Smothering of vegetation Loss of topsoil Local air quality deterioration Disturbance to fauna	Prepare and implement a Dust Management Plan which ensures that: • Exposed surfaces such as stockpiles and cleared areas, and the duration that these areas are exposed, will be minimised. • Dust suppression techniques and/or watering of unsealed roads, access routes, exposed ground surfaces and stockpiles will be implemented. • General housekeeping practices will be undertaken to ensure there is no accumulation of waste materials, within the construction area, that may generate dust. • Ensure that vehicles, machinery and loads are properly maintained and covered to minimise dust emissions. • A Traffic Management Plan will be developed and implemented which will ensure stringent controls on vehicle speeds and restricting travel to designated roads/tracks during construction activities.	Low residual risk

Noise (Terrestrial)	To avoid adverse noise impacts to fauna and people. To ensure that noise emanating from the facilities comply with statutory requirements specified in the Environmental Protection (Noise) Regulations 1997.	Sensitive local receptors on the Burrup Peninsula include Hearson Cove, a popular recreational beach, the existing Dampier Port Authority and associated infrastructure to the south (2 km) of Site A and Site B. The Karratha Gas Plant is located 700 m to the north of Site A and Site B. The nearest residents live in Dampier, approximately 6 km in a straight line south-west of Site A and Site B.	Impacts on business and industrial properties Disturbance to fauna and residences/ sensitive receptors Impacts on residential areas of Dampier Noise impacts from traffic associated with operation workforce Noise impacts from flaring Disturbance to marine fauna including seabirds	Prepare and implement a Noise Management Plan which will ensure: • For construction work outside the hours of 7am to 7pm, and for Sundays and public holidays, Woodside will: • Advise all nearby occupants or other sensitive receptors who are likely to receive noise levels which fail to comply with the standard under Regulation 7, of the work to be done at least 24 hours before it commences. • Submit a Noise Management Plan to the EPA at least seven days before the commencement of construction, with the plan requiring approval by the CEO [EPA]. Measures to be considered include low noise air-cooling fans and acoustic lagging on compressor suction, discharge and recycle piping. Detail design will ensure noise levels from flaring are below the Woodside absolute standard for noise emissions of 115 dB (A) at ground level. Minimising flaring of hydrocarbons by using procedural solutions to reduce flaring to as low as reasonably practicable.	Noise impacts from flaring during commissioning are considered a high residual risk. During operation, noise from flaring is considered medium residual risk. All other impacts are rated as low residual risk.
Vibration and blasting (Terrestrial)	To ensure the safety of construction personnel and members of the general public during blasting operations. To minimise vibration impacts associated with blasting. To minimise impacts to terrestrial and marine fauna. Minimise blasting as far as reasonably practicable.	The main source of vibration and blasting in the Development area has been from blasting undertaken both offshore and on the Burrup Peninsula for activities such as dredging and construction of industry and infrastructure.	Public access to construction sites and their surrounding areas will be restricted during blasting activities Disturbance to residences Disturbance/damage to nearby buildings Direct disturbance to terrestrial fauna	A Blasting Management Plan will be developed and implemented, and will include the following principles: • Smaller, more frequent blasts will be planned using sequential explosive charges to minimise cumulative impacts of the explosions. • Blasting will only be used where absolutely necessary and will be carried out in a manner to reduce noise disturbance to a minimum. • Fauna activities will be taken into consideration when blasting, especially during sensitive periods for the fauna. • Blasting will be scheduled for daylight hours to avoid impacts during peak activity times (dusk, night, dawn) for nocturnal fauna. Explosives will be used in a manner that will minimise damage or defacement of landscape features and other surrounding objects including the following practices: • increasing the depth of material cover • the use of blankets to minimise upward release of energy and fly rock • optimising charge sizes and spacings to avoid unnecessary energy releases.	Direct disturbance to fauna and their habitat during blasting activities is rated as medium residual risk. All other impacts are of low residual risk.

Environmental Factor	EPA/Project Environmental Objective	Existing Environment	Impacts to be Avoided or Minimised	Environmental Management	Predicted Outcome
Noise (Marine)	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act.	The Dampier Archipelago has the richest marine biodiversity known in Western Australia (CALM 2000). The proposed Dampier Archipelago-Cape Preston Marine Conservation Reserves contains a wide range of habitats including mangroves, algal meadows, sandy beaches, submerged soft sediment communities, coral reefs, diverse invertebrate communities, rocky shores and rocky reefs. The Archipelago provides habitat for a number of seabirds and shorebirds which are listed under the EPBC Act. The area also supports sea turtles, dugongs, sea snakes and dolphins and whales.	Disturbance to marine fauna including seabirds and EPBC Act listed species. Behavioural effects, injury or mortality to marine mammals, sea turtles, fish and diving seabirds.	Equipment will be designed to normal petroleum practice, which includes specifications for noise levels, and standard installation and drilling facilities will be used. The interaction of construction and operation vessels and helicopters with cetaceans will be consistent with Part 8 of the EPBC Regulations	Residual risk is low
Blasting (Marine)	To maintain the abundance, biodiversity, productivity and geographic distribution of marine fauna. To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated. To protect Specially Protected (Threatened) Fauna consistent with the provisions of the *Wildlife Conservation Act 1950* (WA) and the EPBC Act. To maintain the integrity and stability of the coast, seafloor and tidal creeks.	The Dampier Archipelago has the richest marine biodiversity known in Western Australia (CALM 2000). The proposed Dampier Archipelago-Cape Preston Marine Conservation Reserves contains a wide range of habitats including mangroves, algal meadows, sandy beaches, submerged soft sediment communities, coral reefs, diverse invertebrate communities, rocky shores and rocky reefs. The Archipelago provides habitat for a number of seabirds and shorebirds which are listed under the EPBC Act. The area also supports sea turtles, dugongs, sea snakes and dolphins and whales.	Shock waves associated with underwater blasting can potentially cause impacts to marine fauna including behavioural changes, physical injury and death (if they are within a close range). Impacts on marine fauna from blasting activities will depend on the size of the charge, the composition of the explosive, water depth, the distance from the explosion centre, and the size and type of species.	Development and implementation of a Blasting Management Plan that will include: • Smaller, more frequent blasts will be planned using sequential explosive charges to minimise cumulative impacts of the explosions. • Marine fauna activities will be taken into consideration when blasting, drilling and/or dredging, especially during sensitive periods for fauna (eg nesting and roosting periods). • Procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence. • To minimise injury to seabird species dead fish on the surface of the water after a blast will be collected to prevent bird injuries or mortality from successive blasts	Residual risk from impacts of marine blasting on fauna is medium

Introduction

1

1.1 Purpose of the PER

This Draft Public Environment Report/Public Environmental Review (referred to as the Draft PER) presents the findings and conclusions of an environmental review undertaken for the proposed Pluto LNG Development by Woodside Energy Limited (Woodside).

The objective of the environmental review process is to ensure that potential environmental impacts associated with the proposed Development during both routine and non-routine operations, are identified and appropriately assessed. In doing so, relevant preventative and management measures can be developed and implemented to ensure that adverse environmental impacts are managed to be As Low As Reasonably Practicable (ALARP). These management measures are outlined in this Draft PER and will be developed further in detailed Environmental Management Plans (EMPs).

The Pluto LNG Development was referred to the Western Australian Environmental Protection Authority (EPA) for assessment in April 2006. The proposal was referred to the Commonwealth Department of the Environment and Heritage (DEH) in August 2006. The DEH and EPA subsequently determined that the proposal should be assessed at the Public Environment Report and Public Environmental Review levels of assessment. This document meets the requirements outlined in the Environmental Scoping document/Guidelines for both state and Commonwealth processes.

The key objectives of this environmental review are to:

- place this proposal in the context of the local and regional environment
- adequately describe all components of the proposal
- provide the basis of the proponent's environmental management programme
- communicate clearly with stakeholders so that the Western Australian EPA and Commonwealth DEH can obtain informed comment to assist in providing advice to their Ministers
- provide a document which clearly sets out the reasons why the proposal should be judged by the EPA, DEH and their Ministers to be environmentally acceptable.

1.2 Development Background

The Pluto gas field was discovered in April 2005 on the North West Shelf, approximately 190 km north-west of Dampier, Western Australia. Preliminary exploration drilling suggests that the Pluto gas field has a Dry Gas contingent resource of 4.1 trillion cubic feet (tcf) with small amounts of recoverable condensate and low levels of carbon dioxide (CO_2).

Woodside is the sole equity holder in Permit WA-350-P, which covers the Pluto gas field, and plans to develop the field through an offshore subsea gathering system which would be tied-back to an offshore platform located in 80–85 m water depth (**Figure 1-1**). Gas will then be exported to shore for further processing. The Development will require two separate sites in the Burrup West Industrial Area on the Burrup Peninsula: a gas processing plant at Lease Area B (Site B) and a hydrocarbon storage and export facility at Lease Area A (Site A).

The Pluto LNG Development will comprise up to two onshore processing trains each with a maximum production capacity of up to 5.9 million tonnes per annum (Mtpa) of Liquefied Natural Gas (LNG), or a total capacity of approximately 12 Mtpa. An expansion of production capacity, which involves the construction of one or more additional LNG trains, is possible but timing (should the expansion eventuate) will be dependent on market and supply variables and hence is not considered as part of this Draft PER.

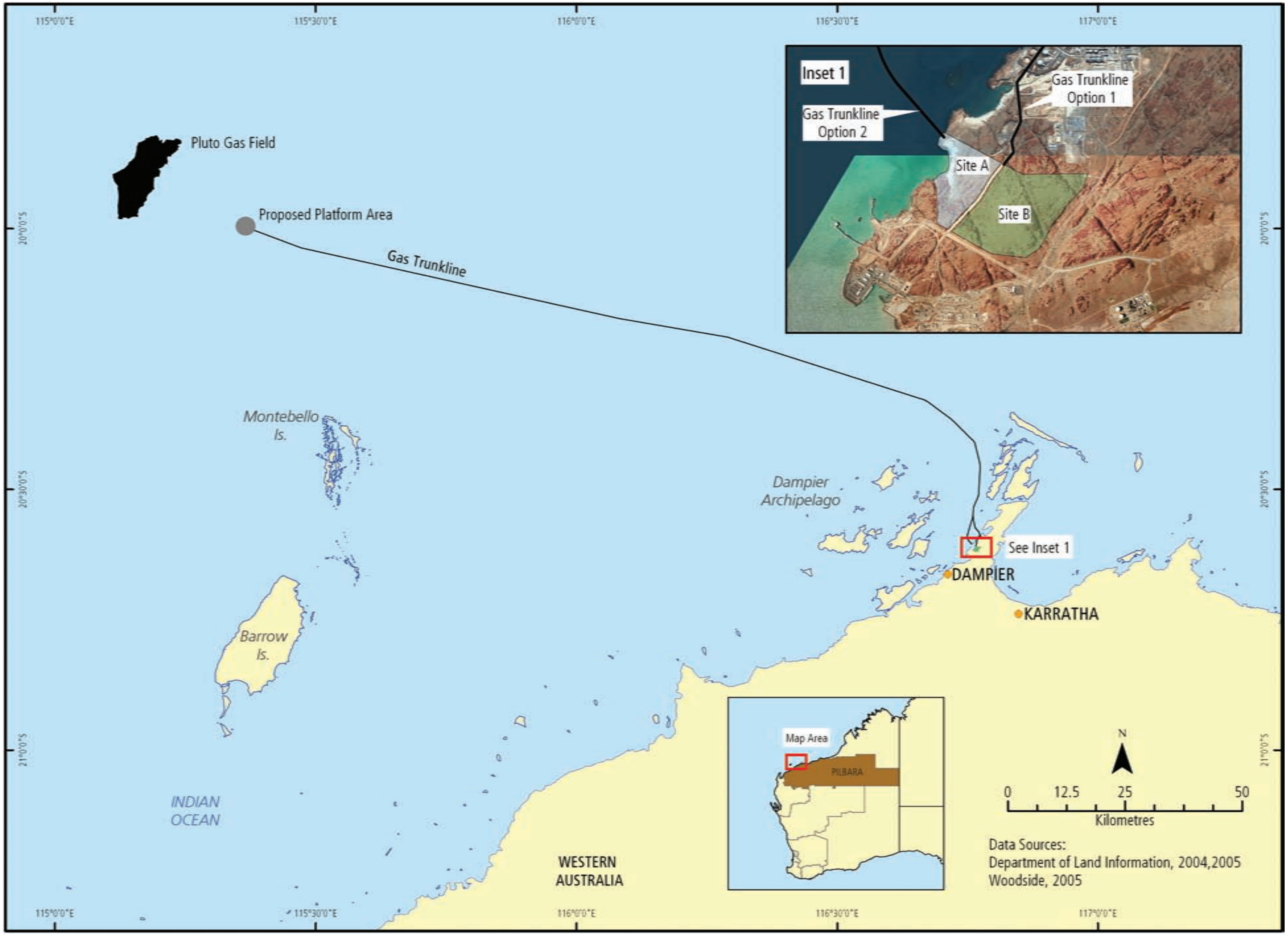
The gas processing plant is being designed to potentially cater for domestic gas supply (Domgas), should favourable market conditions eventuate. It is anticipated that the Domgas capacity will be in the order of 3.5 to 4 Mtpa, however, this capacity will be refined at a later stage.

Total capital investment will be between AUD$6 and AUD$10 billion, with the estimate to be further refined during detailed design.

1.3 Development Proponent

Woodside is the proponent for the proposed Pluto LNG Development and will also be the owner and operator. Woodside is Australia's largest publicly traded oil and gas company and is one of the nation's most successful explorers, developers and producers. The company operates Australia's biggest resource development, the North West Shelf Venture (NWSV) in Western Australia, a project that produces approximately 40% of Australia's oil and gas.

Figure 1-1 Pluto LNG Development Concept



Since the early 1980s, the company has overseen expenditure on the NWSV of more than A$19 billion (US$14 billion) as the Venture has grown into one of the world's leading LNG exporters.

Over the past 50 years, Woodside's business has grown to cover four continents with core areas of focus being Australia, the United States and Africa. In Australia, the company has major exploration and development interests in Western Australia, including the new oil province in the Carnarvon Basin which includes the Enfield, Vincent and Laverda fields, and significant gas discoveries in waters off Victoria and the Northern Territory.

In the United States, Woodside produces gas and oil from fields in the Gulf of Mexico, where it also has an extensive exploration programme in the continental shelf and the deep water. Woodside has offices in Houston, Texas; Covington, Louisiana; and Los Angeles, California.

In Africa, Woodside is operator of the Chinguetti oil project off Mauritania. It is also operator of the Tiof, Tevet and Banda oil and gas discoveries in the same region, and has exploration interests in Libya, Kenya, Sierra Leone, Liberia and the Canary Islands and is a participant in major producing gas and condensate fields in Algeria.

Woodside operates three floating production, storage and offloading facilities: the *Northern Endeavour* is based on the Laminaria and Corallina oil fields in the Timor Sea; the *Cossack Pioneer* is based on the North West Shelf and the *Berge Helene* is based at Chinguetti. Woodside also operates the *Legendre, North Rankin* and *Goodwyn* platforms off Western Australia.

By 2008, the company expects to be producing the equivalent of up to 80 million barrels of oil and gas a year from its LNG, oil, condensate, liquefied petroleum gas and natural gas projects around the world. It also expects to be operating five floating production systems, five major offshore platforms and five LNG processing trains.

At 30 September 2006, Woodside was capitalized at more than A$26 billion. It employs more than 3200 people and has its headquarters in Perth, Western Australia. Woodside has a long record of safe and environmentally sound LNG production with no major incidents in over 15 years operating the NWSV. This record has been recognised through numerous awards.

Woodside is dedicated to a corporate Environmental Policy (**Appendix A**) that provides a public statement of its corporate commitment to protecting the environment during all activities, including offshore exploration and production. The company also has a number of more specific environmental guidelines.

1.4 Development Rationale

The Pluto gas field is being developed to meet a market opportunity in late 2010. Woodside discovered the field in April 2005 and since that time has moved quickly to progress the Development and secure foundation LNG customers.

Two Heads of Agreement have been signed with Tokyo Gas and Kansai Electric, for a combined total of 3.25 to 3.75 Mtpa of LNG, with deliveries starting by the end of 2010 and continuing for 15 years with an option to extend for a further five years. The balance of the Pluto gas reserves will be targeted at the North American market.

The Pluto LNG Development is located in an area where significant offshore reserves of gas exist, although not all reserves are commercially viable to develop on their own. Woodside has developed a commercial model for the Development that provides for other resource owners access to Pluto LNG Development foundation infrastructure with the intention of creating 'Burrup LNG Park' as a potential aggregator for otherwise stranded or yet to be discovered gas fields within the region. Should this occur the Pluto LNG Development has the potential to minimise the long-term footprint of LNG onshore processing facilities in the region.

The Pluto LNG Development will also deliver a range of significant economic benefits to the local area, Western Australia and Australia. These include:

- creation of training, employment and business opportunities
- increased revenue to state and Commonwealth governments
- flow-on economic activity (for example, services and social infrastructure).

Australia's Position in the Global LNG Market

With an estimated 153 trillion cubic feet of discovered gas, Australia has yet to fully capitalise on its potential as a global LNG player.

A strong reputation for reliable supply of LNG has been built by the North West Shelf Venture, which has focussed predominantly on export to Asian markets. Recently a second project, based on the Baya Udan field in northern Australia, came online.

The Pluto LNG Development represents a significant opportunity for Australia to significantly boost its profile in the global LNG market. As well as meeting a market window opportunity to supply premium customers based on the development of the Pluto gas field, the development provides the foundations for a new 'LNG hub' in the Carnarvon Basin. By adopting an open access model which provides the technical and commercial flexibility to aggregate currently stranded regional gas, the Pluto LNG Development has the potential to significantly increase Australia's LNG exports.

Potential Regional Development

Woodside has interests in a number of prospective permits to the north and west of WA-350-P and the Pluto LNG Development represents a potential tie-in point for any gas discoveries. The Pluto LNG Development provides a critical conduit for maximising the value of gas from future discoveries.

The Pluto gas field is located within the Carnarvon Basin and provides the opportunity to aggregate regional gas discoveries, particularly those with low inerts content, for delivery to the Burrup Peninsula.

Over 70 tcf of undeveloped Dry Gas has been discovered in the Carnarvon Basin excluding the North West Shelf Venture acreage. Depending on the sequence of projects in the region, some of these resources may be available to be produced through the Pluto LNG Development infrastructure.

The Development's offshore facilities will be constructed to enable tie-in of third party fields should this be commercially attractive. Discussions are being progressed with the owners of adjacent fields to pursue early commitment to tie-in to the Pluto LNG Development infrastructure. Potential synergies with the existing NWSV Karratha Gas Plant will continue to be explored.

1.5 Scope of the Draft PER

The scope of this Draft PER includes the construction, commissioning, operation and decommissioning of the proposed Pluto LNG Development. A reference case has been developed which represents the most likely development scenario to be pursued. This includes the following key components:

- subsea wells tied-back to an offshore riser platform
- a 42" (1068 mm) diameter gas/condensate trunkline to shore crossing
- an onshore gas/condensate trunkline from shore crossing to the gas processing plant
- an onshore gas processing plant located at Site B
- onshore LNG and condensate storage tanks located at Site A
- a standalone navigation channel, turning basin and berth pocket
- export jetty and causeway
- ancillary facilities.

Site preparation activities for hydrocarbon storage facilities at Site A are covered under a separate PER entitled 'Development of Industrial Land on the Burrup Peninsula for Future Gas Development' (Woodside 2006a). This approach was taken as these facilities require a longer construction lead time than the rest of the Development. Site preparation activities for Site A are therefore not included within the scope of this Draft PER.

1.6 Environmental Approvals Process

This proposal requires environmental assessment by the EPA under Part IV of the *Environmental Protection Act 1986* (WA) (EP Act) and the DEH under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act).

Proposed disposal of dredge material at sea requires approval under Section 19 of the *Environment Protection (Sea Dumping) Act 1981* (Cwth). Disposal of dredge material has been determined a prescribed action under the EPBC Act; hence, assessment of dredge spoil disposal is required under the EPBC Act before consideration can be given to issuing a sea dumping permit.

To initiate the state environmental assessment process, a referral and an Environmental Scoping document was submitted to the EPA in April 2006 (Woodside 2005a and 2005b). The EPA determined that the proposal should be formally assessed at the Public Environmental Review level of assessment.

In parallel to the state process, the proposal was also referred to DEH under the EPBC Act (1 August 2006, DEH reference No. 2006/2968), and was subsequently deemed a 'controlled action' on 24 August 2006. The controlling provisions (that is, those matters deemed significant for this proposal) for the action under the EPBC Act are:

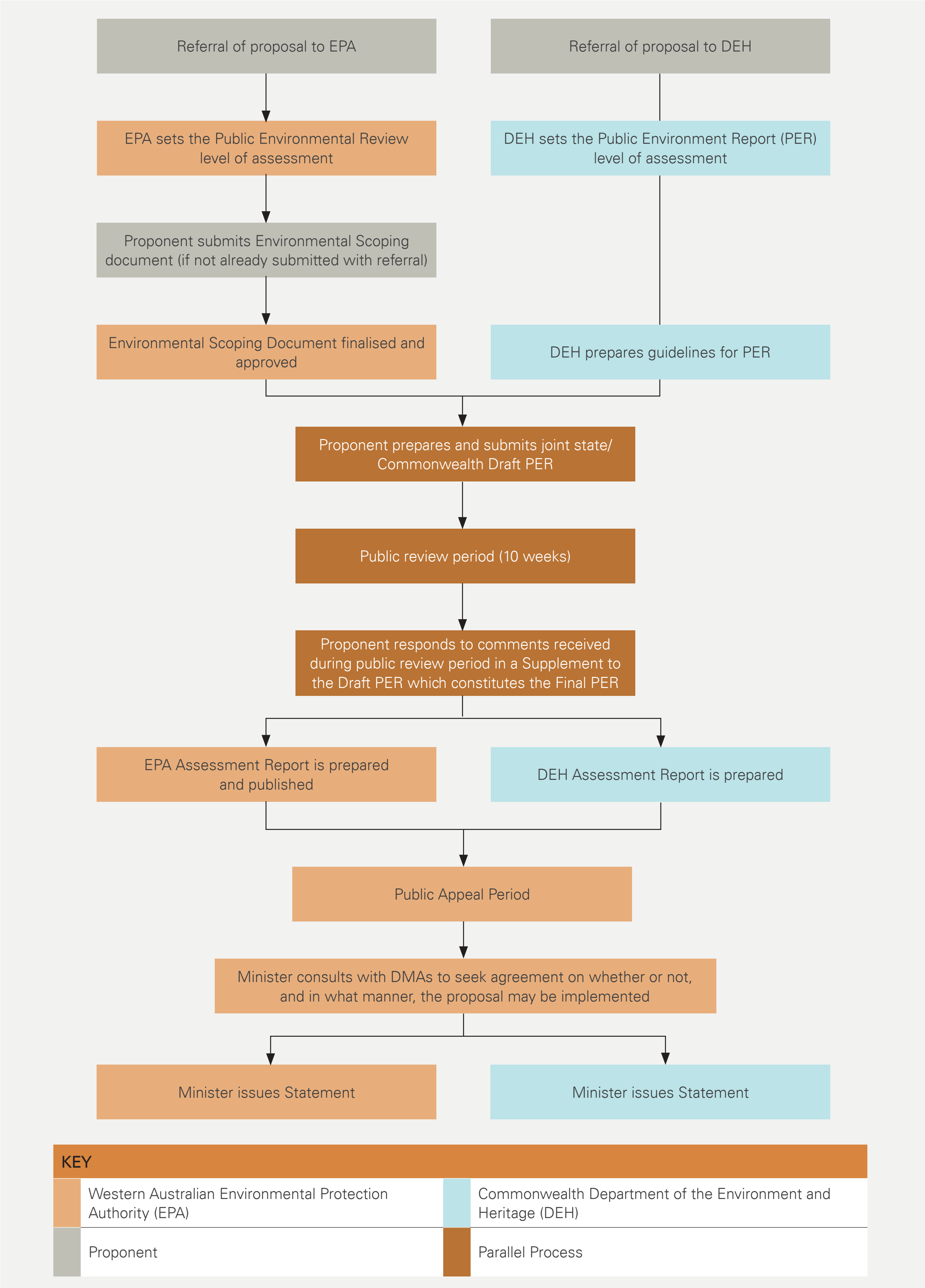
- Sections 18 and 18A (listed threatened species and communities)
- Sections 20 and 20A (listed migratory species)
- Sections 23 and 24A (marine environment).

Species of particular interest under the EPBC Act include the following:

- Pilbara olive python (*Liasis olivaceus barroni*)
- northern quoll (*Dasyurus hallucatus*)
- southern giant petrel (*Macronectus giganteus*)
- Pilbara leaf-nosed bat (*Rhinonicteris aurantius*, Pilbara form)
- green turtle (*Chelonia mydas*)
- flatback turtle (*Natator depressus*)
- hawksbill turtle (*Eretmochelys imbricata*)
- loggerhead turtle (*Caretta caretta*)
- blue whale (*Balaenoptera musculus*)
- humpback whale (*Megaptera novaeangliae*).

The DEH determined on 21 September 2006 that assessment by PER is the approach to be followed.

Figure 1-2 EPA and DEH Coordinated PER Assessment Approach



The Draft PER has been prepared to satisfy both regulatory bodies and will be submitted to both the Western Australian and Commonwealth governments simultaneously under a joint assessment process. This Draft PER has been prepared in accordance with the final approved Environmental Scoping document and Guidelines which provide guidance on the environmental factors to be assessed and the level of investigation required to address potential impacts.

The Draft PER is subject to review by stakeholders and the general public for a period of ten weeks. Once the public comment period is closed, Woodside will formally respond to comments made in a Supplement to the Draft PER to the satisfaction of the Minister as required under s99 of the EPBC Act. This document along with the Draft PER will constitute the Final PER. The EPA and DEH will then review Woodside's responses to the public submissions and prepare separate environmental assessment reports for both the state and Commonwealth Environment Ministers. At the conclusion of the assessment, the Commonwealth Minister for the Environment and Heritage is responsible for considering the issue of an approval in relation to the matters protected under the EPBC Act. Both Ministers will then issue a statement as to whether the proposal may be implemented, and if so, on what conditions. A flow chart summarising the approval process is presented in **Figure 1-2**.

1.6.1 Guidelines, Standards and Codes

EPA Guidance Statements

Guidance Statements are issued by the EPA to assist proponents, and the public generally, to understand the minimum requirements that the EPA expects to be met during the assessment process, for the protection of elements of the environment. Accordingly, during studies and investigations for this Draft PER, the following guidelines have been considered and applied where appropriate:

- Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 1 (Final)
- Risk Assessment and Management: Offsite Individual Risk from Hazardous Industrial Plant – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 2 (Final)
- Separation Distances between Industrial and Sensitive Land Uses – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 3 (Final)
- Minimising Greenhouse Gases – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 12 (Final)
- Emissions of Oxides of Nitrogen from Gas Turbines – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 15 (Final)
- Prevention of Air Quality Impacts from Land Development Sites – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 18 (Final)
- Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 29 (Final)
- Linkage between EPA Assessment and Management Strategies, Policies, Scientific Criteria, Guidelines, Standards and Measures Adopted by National Councils – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 34 (Final)
- Assessment of Aboriginal Heritage – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 41 (Final)
- Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 51 (Final)
- Implementing best practice in proposals submitted to the environment impact assessment process – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 55 (Final)
- Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia – Guidance for the assessment of environmental factors (in accordance with the EP Act 1986) No. 56 (Final).

Other Applicable Guidelines

Other applicable national and international guidelines include the following:

- Water Quality Monitoring and Reporting – Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines 2000
- Ballast Water Guidelines – AQIS 2001
- National Code of Practice for the Storage and Handling of Dangerous Goods – National Occupational Health and Safety Commission 2001
- National Standards for the Control of Major Hazard Facilities – National Occupational Health and Safety Commission 2002
- Oil Companies International Marine Forum Guidelines 1981–2004
- International Safety Guide for Oil Tankers and Terminals Guidelines 1996
- Guidelines for Naturally Occurring Radioactive Materials – APPEA 2002
- National Ocean Disposal Guidelines for Dredged Material 2002.

It is noted that *The Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives* was released in June 2006 (DoE 2006a). This document establishes an Environmental Quality Management Framework (EQMF) and presents the EPA's interim set of environmental goals (Environmental Values and Environmental Quality Objectives) and spatially allocates these goals (Levels of Ecological Protection) for state waters of the Pilbara coast (DoE 2006a). These levels are allocated based on specific target environmental quality conditions and range from *Low* for existing industrial discharges, *Medium* for existing developed areas including shipping berths and spoil grounds, *High* for unzoned areas including port areas through to *Maximum* for areas of environmental significance.

It is acknowledged that the Levels of Protection have been spatially allocated to Mermaid Sound and while a comprehensive set of Environmental Quality Criteria on which these Levels of Protection wil be based has yet to be formally established, they are likely to be based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000). It is envisaged that the level of Ecological Protection allocated to the Pluto LNG Development nearshore marine infrastructure area will be commensurate with the level allocated to exisiting industrial development areas in Mermaid Sound. The other four Environmental Values, collectively referred to as social-use values, represent specific human benefits or uses that rely on a clean, healthy marine environment. They are:

- fishing and aquaculture
- recreation and aesthetics
- cultural and spiritual and
- industrial water supply.

These values have been considered during assessment of potential impacts to social values in the vicinity of the Pluto LNG Development and will be considered development of marine monitoring programmes.

1.6.2 Applicable Legislation

Some of the applicable Western Australian and Commonwealth statutes and regulations under which the Development will be constructed and operated are listed in **Table 1-1**. Applicable international agreements are included in **Table 1-2**.

Table 1-1 Key Western Australian and Commonwealth Statutes and Regulations

Western Australian Legislation	Legislation Summary
Environmental Protection Act 1986	This is the principal statute pertinent to environmental protection in WA. It gives the EPA overall responsibility for the prevention, control and abatement of environmental pollution and for the conservation, preservation, protection, enhancement and management of the environment.
Environmental Protection (Noise) Regulations 1997	These regulations provide guidelines for noise assessment and control, and set noise limits to ensure that noise from premises are kept to acceptable levels.
Conservation and Land Management Act 1984	This Act provides for the use, protection and management of public lands, including parks and forests. It includes water, flora and fauna on these lands. The Department of Environment and Conservation (DEC) administers the Act.
Petroleum Act 1967; Schedule of Onshore Petroleum Exploration and Production Requirements 1991	This Act and the Schedule relate to the exploration for, and the exploitation of, petroleum resources within certain lands of Western Australia, including vacant Crown land.
Petroleum (Submerged Lands) Act 1982 and Regulations 1990	This Act and its regulations provide for the exploration and exploitation of petroleum resources on submerged lands adjacent to the coast of Western Australia.
Petroleum Pipelines Act 1969 (Section 8) and Regulations 1970	This Act and its regulations relate to the construction, operation and maintenance of pipelines for the conveyance of petroleum.
Fish Resources Management Act 1994 and Regulations 1995	This Act and its regulations are concerned with commercial exploitation and development of fisheries and marine resources. Under the Act, development projects must be carried out so as not to adversely impact on fisheries and marine resources.
Marine and Harbours Act 1981 and Marine and Harbours (Fuelling) Regulations 1985	This Act contains regulations to control the refuelling of ships and boats and is administered by the Department of Planning and Infrastructure (DPI).
Pollution of Waters by Oil and Noxious Substances Act 1987; Pollution of Waters By Oil and Noxious Substances Regulations 1993	This Act prohibits the discharge of oil or noxious substances into Western Australian state waters, and provides for the removal of oil or any mixture containing oil from affected waters. The harbour authority or the DPI administers the Act.
Aboriginal Heritage Act 1972 and Regulations 1974	This Act applies to the protection of registered significant archaeological, anthropological and historical sites and objects with traditional or current sacred, ritual or ceremonial significance to persons of Aboriginal descent in WA.
Agriculture and Related Resources Protection Act 1976	This Act imposes controls for the containment of pests and weeds.
Explosives and Dangerous Goods Act 1961 and Regulations 1963; Explosives and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations 1992	This Act imposes controls for storage and handling of dangerous and explosive goods.
Soil and Land Conservation Act 1945 and Regulations 1992	This Act and its regulations relate to the conservation of soil and land resources, and to the mitigation of the effects of erosion, salinity and flooding.

Wildlife Conservation Act 1950 and Regulations 1970	This Act and its regulations provide for the protection of native flora and fauna, including rare or endangered species.
Health Act 1911 (Part IV)	This Act consolidates and amends the law relating to public health. In particular Part IV and V relate to sanitary provisions and dwellings respectively.
Commonwealth Legislation	**Legislation Summary**
Environment Protection and Biodiversity Conservation Act 1999	This Act protects the environment, particularly matters of National Environmental Significance (NES). It streamlines national environmental assessment and approvals process, protects Australian biodiversity and integrates management of important natural and culturally significant places.
Petroleum (Submerged Lands) Act 1967	This Act relates to the exploration and exploitation of petroleum resources in the area of the continental shelf of Australia and certain Territories of the Commonwealth. In this case, Commonwealth law applies to areas beyond three nautical miles (nm) off the mainland coast.
Petroleum (Submerged Lands) (Occupational Health and Safety) Regulations 1993	This regulates matters pertaining to occupational health and safety on offshore facilities.
Petroleum (Submerged Lands) (Management of Environment) Regulations 1999	These regulations ensure that petroleum activities in Commonwealth waters are carried out in an ecologically sustainable manner and as directed in the proponents Environment Plan.
Management of Safety of Offshore Facilities Regulations 1996 (and the subsequent amendments)	These regulations ensure that offshore facilities are installed, operated and modified in Commonwealth waters in accordance to the Safety Authority and that all risks have been identified and mitigated through constant monitoring, audits and reviews.
Historic Shipwrecks Act 1976	This Act protects shipwrecks that have lain in territorial waters for 75 years or more. It is an offence to interfere with any shipwreck covered by the Act.
Australian Heritage Council Act 2003	This Act identifies areas of heritage value listed on the Register of the National Estate and sets up the Australian Heritage Council and its functions.
Environment Protection (Sea Dumping) Act 1981	This Act regulates permitted sea dumping and under the 1996 Protocol to the London Convention Australia is required to minimise its waste disposal into the marine environment. Approval is required under this Act for the disposal of dredged material at sea.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act disallows any harmful discharge of sewage, oil and noxious substances into the sea and sets the demands for a shipboard waste management plan.
Quarantine Act 1908	This Act implements mandatory controls in the use of seawater as ballast in ships and the declaration of sea vessels voyaging out of and into Commonwealth waters.
Quarantine Regulations 2000	These regulations stipulate that all information regarding the voyage of the vessel and the ballast water is declared correctly to the quarantine officers.
Submarine Cables and Pipelines Protection Act 1963	The breaking or injuring of submarine cables and/or pipelines is a punishable offence under this act, and the penalties include fines and/or imprisonment.
Civil Aviation Act 1988	This Act provides a regulatory framework to maintain, enhance and promote the safety of civil aviation; especially in the prevention of aviation accidents and incidents.
Navigation Act 1912	This Act requires that ships carrying oil and chemical tankers conform to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL).

Table 1-2 International Agreements

International Agreements	Agreement Summary
The Japan-Australia Migratory Bird Agreement (1974) (JAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan.
The China-Australia Migratory Bird Agreement (1986) (CAMBA)	This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China.
United Nations Convention on the Law of the Sea 1982 (UNCLOS)	This convention recognises the desirability of establishing a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment.
Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (1979)	The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species.
International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC 90)	This convention comprises national arrangements for responding to oil pollution incidents from ships, offshore oil facilities, sea ports and oil handling. The Convention recognises that in the event of pollution incident, prompt and effective action is essential.
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	This convention aims to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimisation of accidental discharge of such substances.

Stakeholder Engagement 2

2.1 Consultation to Date

This Draft PER represents a means by which stakeholders in the Pluto LNG Development may gain an understanding of the proposal, the alternatives, the environment that it would affect, the potential impacts that may occur and the measures proposed to avoid or minimise those impacts.

Woodside views public involvement in environmental assessment as a critical factor and more than a statutory requirement. During the preparation of this Draft PER, Woodside has consulted with a broad range of stakeholders with the aim of:

- Briefing stakeholders on the development concept and fostering an understanding of Woodside's objectives and timeline for the Development.
- Presenting stakeholders with the key environmental factors associated with the Development and potential impacts and proposed environmental management strategies.
- Gaining feedback from stakeholders on the environmental, social and heritage aspects of the proposed development.
- Providing Woodside with the opportunity to demonstrate commitment to achieving a high level of environmental performance through its environmental management approaches for the development.

A range of methods have been used to consult with stakeholders, including:

- open community meetings
- targeted stakeholder meetings
- correspondence
- phone conversations
- workshops.

Woodside aimed to directly engage stakeholders early in the project planning and environmental assessment processes and will continue throughout all phases of the Development to ensure that issues raised by stakeholders are identified and appropriately addressed.

The Woodside Karratha Community Liaison Group includes community, government and business representatives and will be consulted extensively about environmental, social and cultural heritage impacts and their management, throughout the construction and operation of the Pluto LNG Development.

Specific consultations with Indigenous groups have been and will continue to be arranged as required, particularly in relation to cultural heritage matters.

During the preparation of this Draft PER, Woodside made contact with a range of government departments, community groups and individuals, as shown in **Table 2-1**. Key issues raised by stakeholders included:

- site selection process
- physical destruction or removal of cultural heritage
- potential flora and fauna impacts
- potential impacts to the marine environment associated with dredging
- housing (construction and operations workforce).

Table 2-1 Stakeholders Contacted by Woodside

Name of Organisation or Individual Consulted		
Australian Institute of Marine Science (AIMS)	International Federation of Rock Art Organisations	Pilbara Development Commission
Australian Petroleum Production and Exploration Association (APPEA)	Invest Australia	Premier of Western Australia
Appeals Convenor (WA)	Karratha Community	Robin Chapple
Burrup Fertilisers Pty Ltd	LandCorp	Shire of Ashburton
Chamber of Minerals and Energy of Western Australia	Main Roads Western Australia (MRWA)	Shire of Roebourne
Commonwealth Members of Parliament	Mardudhunera people	State Members of Parliament
Conservation Council of WA	Maritime Union of Australia	Thalanyji people
Dampier Port Authority (DPA) and Spoil Ground Management Committee	Marine and Coastal Community Network	Tourism Council of Western Australia
Department of Consumer and Employment Protection (WA)	Marine Coastal Strategy Group	Western Australian Fishing Industry Council
Department of Environment and Conservation (North-West Region and Perth) (WA)	Minister for State Development (WA)	Leader of the Opposition (WA)
Department of the Environment and Heritage (Commonwealth)	National Trust of Australia (WA)	Water Corporation (WA)
Department of Indigenous Affairs (WA)	Ngarluma people	Minister for Resources Development (WA)
Department of Industry and Resources (WA)	Office of Development Approvals Coordination (WA)	Wong-Goo-Tt-Oo people
Department of Industry, Tourism and Resources (Commonwealth)	Office of Shadow Minister for Industry, Infrastructure and Industrial Relations (Commonwealth)	World Wildlife Fund (WWF)
Department of Planning and Infrastructure (WA)	Office of the Minister for Tourism Industry and Resources (Commonwealth)	Yindjibarndi people
Environmental Protection Authority (WA)	Office of Native Title (WA)	Yaburara people
Geoscience Australia	Office of the Minister for the Environment (WA)	Minister for Indigenous Affairs (WA)
Hamersley Iron	Onslow Community	Premier of Western Australia

Development Alternatives 3

3.1 Introduction

This section describes Woodside's site selection process and the factors which have led to the selection of the Burrup Peninsula as the preferred onshore location for the Pluto LNG Development.

Woodside has assessed a range of development alternatives for the Pluto LNG Development. For the onshore components of the Development, this has included a regional assessment of potential development locations and investigation of design options at alternative development sites.

3.2 Site Selection Process

The site selection process followed a logical step-wise approach as illustrated in **Figure 3-1**. The approach used was to identify a number of suitable sites that generally complied with development, environmental and socio-economic criteria and then analyse the alternatives to converge on a shortlist of sites that could be taken forward to final site selection.

Extensive engineering studies have been conducted to support the site selection study. In addition, alternative development locations have been discussed with government, non-government organisations (NGOs) and local communities.

3.2.1 Definition of Regional Site Selection Criteria

The first step in the site selection process involved identification of the physical, broad environmental and socio-economic criteria which could be applied to identify potential regional development locations. It is recognised that no single site will fully meet all of the physical, environmental and socio-economic criteria. Woodside's goal therefore was to find the site that best fit the most number of criteria. Physical, environmental and socio-economic criteria are outlined in **Table 3-1** to **Table 3-3**.

Figure 3-1 Site Selection Process

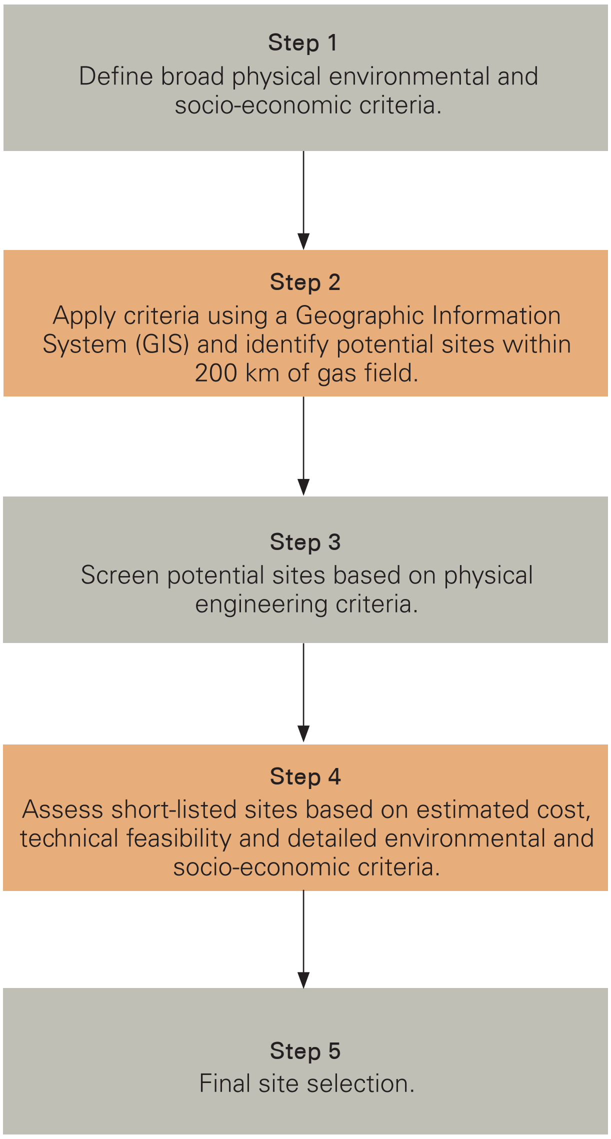


Table 3-1 Broad Physical Development Requirements and Constraints

Criteria	Target
Proximity to gas field	Onshore gas processing plant and associated facilities to be located within 200 km of gas field.
Sufficient available area	At least 200 ha of land available for development.
Site elevation	Minimum to be Australian Height Datum (AHD) + 7 m for final ground level.
Proximity to coastline	LNG storage within 500 m of berth; gas processing plant to be located as close as possible to the storage facility.
Inshore trunkline approach and access	Minimise inshore stabilisation. Require corridor for gas supply trunkline.
Ruggedness of topography	Aim for balance cut-to-fill on bulk earthworks.
Proximity to deep water	Lowest Astronomical Tide – 13.5 m deep water as close as possible to the site. A distance of 10 km was adopted as a limit for screening.
Sheltered water for an LNG berth	Shipping berth must be located within sheltered, navigable waters (that is, preferable within sheltered embayments or lee sides of islands and peninsulas).
Proximity to existing infrastructure	Preference for locations with existing infrastructure.

Table 3-2 Broad Environmental Constraints

Criteria	Target
Conservation reserves	Existing and proposed terrestrial and marine conservation reserves to be avoided.
Mangroves	Avoid mangrove areas identified by the EPA as 'regionally significant'. Minimise disturbance to other areas of mangroves.
Declared rare flora	Adopt an exclusion zone in areas where declared rare flora species are known to occur.
Fauna species and habitats	Avoid areas of critical habitat for state or Commonwealth threatened species. Avoid listed threatened ecological communities.
Saline coastal flats	Avoid saline coastal flats.
Water courses	No development within 100 m proximity of permanent or significant ephemeral watercourses.
Groundwater reserves	No development in areas where prescribed groundwater reserves exist.

Table 3-3 Broad Socio-Economic Criteria

Criteria	Target
Mineral deposits and tenements	Development to avoid mineral deposits and tenements.
Near other leases (for example, pearl farming, salt production)	No development within 2 km of areas covered by pearling or salt leases.
Residential development	Development to be outside of a radius of approximately 2–3 km of urban developments.
Tourism and recreation reserves	No development within 2 km of tourism and recreation reserves or specific attractions or venues.
Aboriginal heritage sites	Ability to minimise impact in areas where high densities of significant Aboriginal heritage sites occur.
Native Title	Minimise impact on Native Title.

Figure 3-2 Regional Site Locations

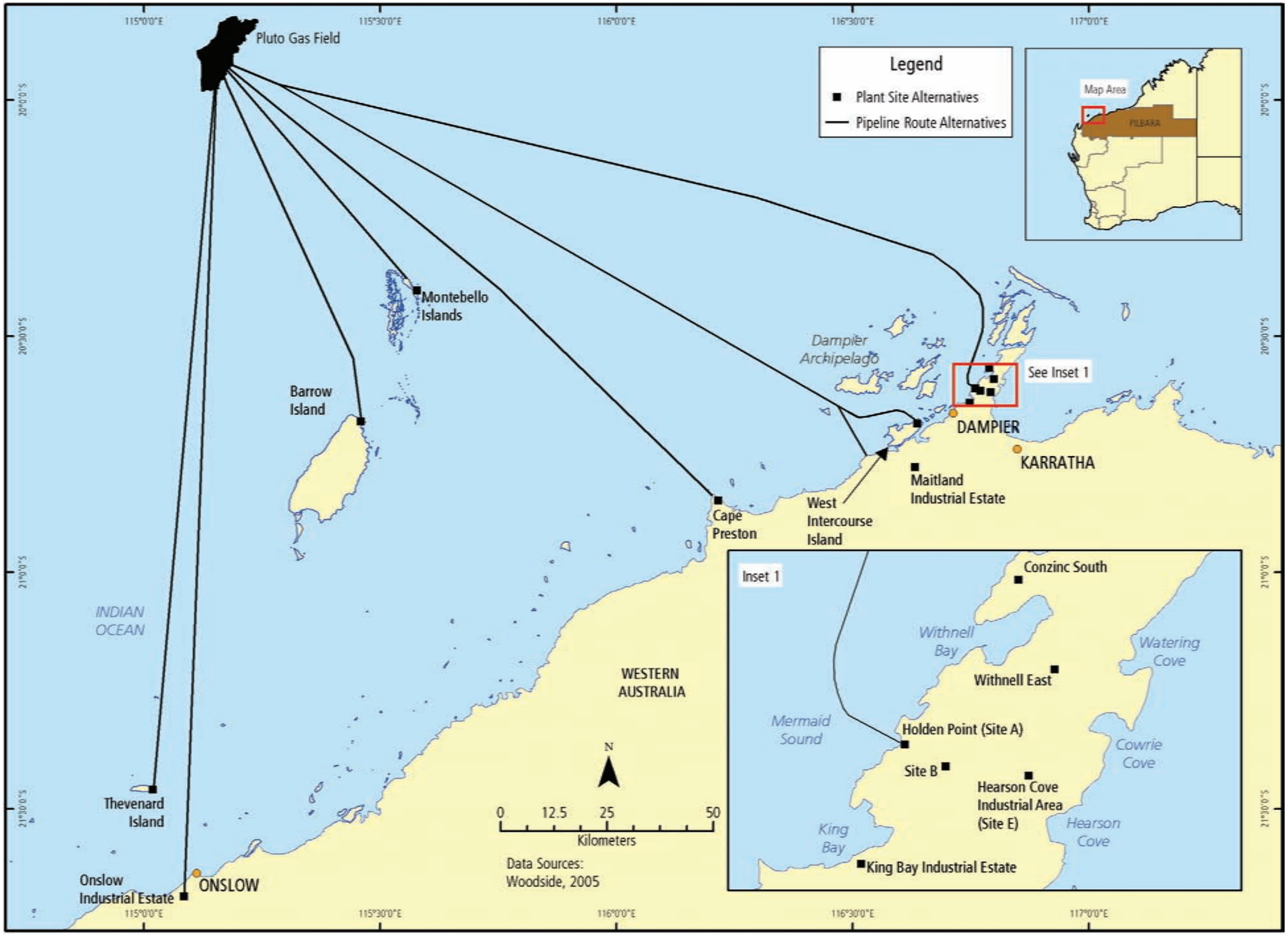
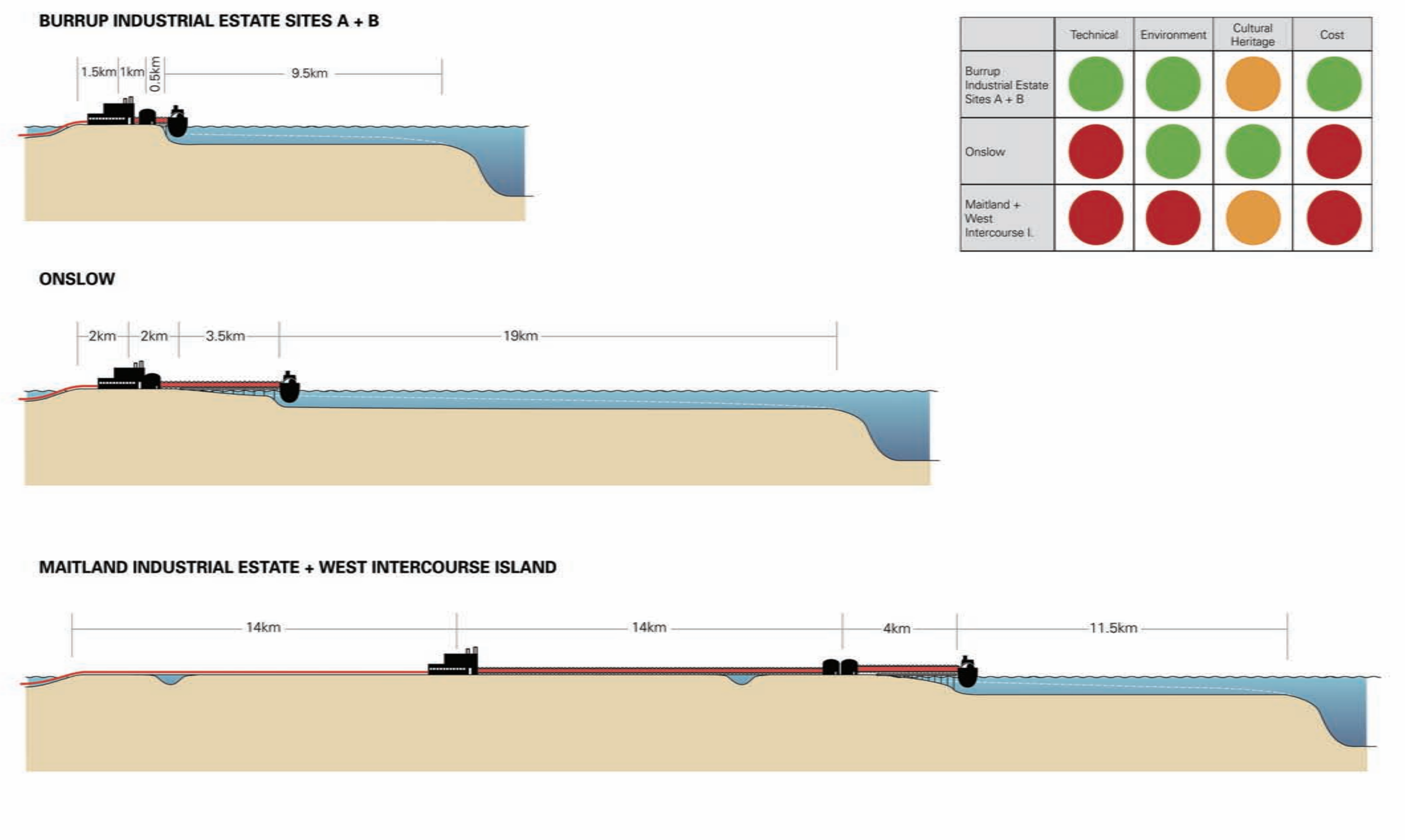


Figure 3-3 Comparison of Development at Holden Point (Burrup Peninsula), Onslow and the Maitland Industrial Estate



3.2.2 Identification of Regional Alternatives

Once broad physical, environmental and socio-economic criteria were defined, Woodside's Geographic Information System (GIS) was used to identify regional locations which met these criteria at a macro level. This process focussed on the defined target region which is a radius of 200 km around the Pluto gas field and encompassed sites from Onslow in the south to Conzinc Island in the north. For the Pluto LNG Development, it is uneconomic to transport gas for processing over distances longer than 200 km.

The following 12 sites were identified as having potential for development and were carried forward for further screening (refer to **Figure 3-2**):

1) Trimouille Island (Montebello Islands)
2) Thevenard Island
3) Barrow Island
4) Onslow
5) Cape Preston
6) West Intercourse Island
7) West Intercourse Island and Maitland Industrial Estate
8) King Bay Industrial Estate (Burrup Peninsula)
9) Burrup Industrial Estate - Site A and Site B
10) Burrup Industrial Estate – Site A and Site E
11) Withnell East (Burrup Peninsula)
12) Conzinc South (Burrup Peninsula).

The Maitland Estate, about 20 km south-west of Karratha, was rejected in the early stages of site selection for the onshore components of the Development. It was eliminated primarily because of factors relating to lack of access to deep water, distance from the coast, impacts on mangroves and wetlands, and heritage considerations (refer to **Figure 3-3**).

Maitland Estate does not represent a technically or commercially viable option. The Maitland Estate is inland and has no port facilities, which means it could not be used for some onshore components of an LNG development. Liquefied natural gas storage tanks must be close to export facilities, which require deep water access. The nearest suitable site is on West Intercourse Island, about 14 km away.

Development at Maitland Estate would require a 14 km cryogenic (refrigerated) LNG export pipeline to West Intercourse Island, potentially requiring chilling stations along the way, a 10 km causeway and bridge system over the Maitland River delta and flood plain which consists of coastal mangroves of high conservation significance.

Development of storage and export facilities on West Intercourse Island would also require a 1 km causeway from the mainland for vehicular traffic and the LNG export pipeline. Such a structure could potentially interfere with current flows within the channel resulting in potentially significant long-term impacts to the surrounding coastal environment including areas of mangrove habitat.

3.2.3 Initial Screening of Regional Alternatives

Each of the 12 sites identified in Step 2 were subject to an 'on-ground' inspection and screening process, which considered all sites from an engineering feasibility perspective. Physical parameters included sufficient elevation, ruggedness of topography, access to deep water, adequate sheltered water, sufficient development area (200 ha) and access to infrastructure.

Seven locations did not satisfy physical engineering requirements and were excluded from further consideration. Five sites remained for further assessment based on estimated capital cost and detailed environmental and socio-economic criteria. These were:

1) Onslow
2) West Intercourse Island
3) The Burrup Industrial Estate – Site A and Site B
4) The Burrup Industrial Estate – Site A and Site E
5) Conzinc South (Burrup Peninsula).

3.2.4 Assessment of Short-listed Sites

The five sites short-listed in Step 3 were further assessed based on estimated costs, technical feasibility and detailed environmental and socio-economic criteria, and a number of key Woodside commercial considerations.

Engineering concepts were established for each of the alternative sites and the overall cost of developing each site estimated. Key factors which impacted the relative cost of alternative sites were:

- length and difficulty of constructing the offshore and onshore sections of the feed gas trunkline
- volume of the necessary site earthworks and hardness of material
- length of the cryogenic LNG run-down line
- length of the jetty and associated LNG loading system
- volume of dredging required to provide a turning basin and shipping channel and the hardness of the material to be dredged
- need for remote or offsite infrastructure to support construction and operation of the gas processing plant
- preliminary construction plan and operating philosophy (for example, local employment versus fly-in fly-out).

Detailed environmental and socio-economic criteria were developed in consultation with stakeholders, and are presented in **Table 3-4**. The assessment of alternative sites against these criteria was based on existing baseline survey data—cultural heritage and fauna survey data were available for some of the sites at the Burrup Peninsula and Onslow—and a literature review and stakeholder consultation. Vegetation and nearshore marine surveys were also conducted at all sites except Conzinc South.

Table 3-4 Detailed Environmental and Socio-Economic Criteria

	Criteria	Key Issues
Socio-economic	Existing Land Use	Industrial
		Pastoral
		Traditional
	Existing Intertidal Use	Recreational fishing
		Community recreational use
	Existing Marine Use	Recreational fishing
		Commercial fishing
		Navigation and shipping
		Aquaculture and pearling
		Tourism and recreation
	Cultural Heritage	Marine archaeology
		Rock art/ petroglyphs
		Terrestrial archaeology
		Ethnographic sites
		National heritage
		World heritage
	Local Community	Resettlement
		Housing
		Health
		Transport
		Population
		Social infrastructure
		Community governance capacity
		Community capacity to respond
		Communications
		Power supply
		Vulnerable groups
		Water supply
		Educational areas
		Neighbouring communities
	Local Economy	Micro-economic impact
		Land values
		Employment and wages
		Local businesses
		Inflationary pressures
		Tourism
		Third party impacts
	Land Ownership	Existing land tenure
		Native title
	Cumulative Impacts	Other existing projects

	Criteria	Key Issues
Environmental	Flora and Vegetation	Declared rare flora
		Priority flora
		Regionally significant biodiversity
	Habitat	Threatened species (EPBC Act)
		Threatened ecological communities (EPBC Act)
	Fauna	Benthic primary producers
		Ramsar wetlands
		Threatened species (EPBC Act/*Wildlife Conservation Act 1950*)
		Migratory species
		Regionally significant biodiversity
		Short-range endemic species
	Conservation Estate	Marine parks
		Marine nature reserve
		Marine management areas
		National parks
		Nature reserve
		Conservation parks
		Regionally significant areas
		World heritage
		Proposed conservation areas
	Landform	Watercourses
		Groundwater
		Saline coastal flats
		Karstic systems
		Water supply (regional)

3.2.5 Final Site Selection

Conzinc South was discounted because of the estimated high development cost associated with the rugged terrain at this site which would make construction difficult. Access from the sea is also complicated by the presence of two existing gas trunklines to the south-west of the site which service the NWSV Karratha Gas Plant. Lastly, consultation with stakeholders indicated that development on the Burrup Peninsula to the north of the existing Karratha Gas Plant is not preferred over development within the southern sections of the Burrup Industrial Estate.

Development of a gas processing plant and associated storage and export facilities on West Intercourse Island would require the construction of a large causeway to access the island. This would not only incur significant additional development costs over alternative sites but would also result in significant impacts to the environment and other industries in the area. West Intercourse Island is culturally important and is ecologically intact. Siting LNG storage tanks and other facilities at the northern end of the island would require disturbance of an area of about 30 hectares. West Intercourse Island was therefore discounted as a final preferred site for the gas processing plant and associated storage and export facilities.

Onslow and the Burrup Industrial Estate option (Sites A and Site E) were carried as alternative locations after other sites had been discounted. Significant engineering work and assessment of cost, technical, environmental and socio-economic factors was undertaken for these development options.

Onslow currently carries a range of uncertainties that are considered to present a significant risk to Woodside's development timeframe for the Pluto LNG Development. Onslow presents technical and cost challenges for the Development particularly with regard to capital and operational costs associated with marine facilities (that is, length of jetty and shipping channel) and marine operability (that is, sea-state) off Onslow (**Figure 3-3**). Other uncertainties include the unresolved status of industrial sites south of Onslow, existing Native Title claims which have not yet been determined, limited existing community infrastructure and lack of government support for a development of this size in this area and timeframe.

Development at Site A and Site E within the Burrup Peninsula Industrial Estate was initially the preferred location for the Pluto LNG Development. This decision was based on evaluation of a range of engineering, environmental, socio-economic and cost criteria and the unavailability at the time of Site B.

In particular, the advantages of development within the Burrup Peninsula Industrial Estate include:

- Location within a designated industrial estate with significant existing common-user infrastructure.
- Certainty over Native Title which has been extinguished on the Burrup Peninsula.
- Significantly lower development cost compared to Onslow. Construction of a 3 km jetty and dredging a lengthy access channel (approximately 19 km) at Onslow results in substantial additional capital cost over the Burrup Peninsula option.
- Proximity to the regional centres of Karratha and Port Hedland which contain existing community infrastructure with a greater capacity to cope with a major development.
- Existing knowledge of the Burrup Peninsula. There have been numerous proposals and associated studies conducted on the Burrup Peninsula over the years resulting in a good understanding of the existing ecological, socio-economic and physical attributes, including metocean and geology, and the potential risks associated with development in the area.
- Ability to draw on Woodside's experience in operating the Karratha Gas Plant on the Burrup Peninsula.

Location of storage and export facilities at Site A and the gas processing plant at Site E formed the reference case for the Development until mid 2006. In early 2006 the Western Australian Government requested that Woodside assess the feasibility of locating the gas processing plant at Site B which is located immediately adjacent to Site A. Site B was initially discounted as a potential site for the gas processing plant because at the time of site selection Site B was already allocated by the state government to another proponent. However, from a planning perspective it has always been the state's preference to allocate the western fringe of the industrial estate north of King Bay to LNG production.

Woodside has undertaken a range of studies to investigate the feasibility of siting the gas processing plant at Site B. This work has demonstrated that Site B presents a number of benefits over development at Site E, including:

- Improved integration between gas processing site and storage and export facilities including reduced operational safety risks.
- Reduced infrastructure requirements, for example no requirement for a lengthy service corridor between sites, leaving the state's significant investment in common user infrastructure available for other proponents.
- Reduced impact on heritage landscape including significantly reduced requirement for land on Site A

Site A and Site B on the Burrup Peninsula have therefore been selected as the preferred onshore gas processing plant location for Pluto LNG Development.

3.3 Offshore Platform Concept

Selection of a suitable platform location for the offshore platform was undertaken in three stages:

- Stage 1 – Survey sufficient area to cover potential locations in the vicinity of the Pluto gas field.
- Stage 2 – Identify environmental constraints and cost drivers and assess to select a preferred area.
- Stage 3 – Refine preferred area.

Following optimisation of flowline lengths, water depth and geotechnical foundation requirements, the platform location was selected in 85 m water depth in an area of suitable foundation quality.

The objective of the offshore development is to enable the production of gas and associated liquids from the Pluto gas field, and to transport the products to an onshore gas processing plant. The approach taken to meet this objective was to select a highly reliable offshore production system, using proven technology.

The offshore concept selection process considered a range of development options which were grouped into themes and screened using defined selection criteria. Each of the five themes is described below:

- Theme A – subsea tieback to a fixed platform on the continental shelf providing gas dehydration, water treatment, hydrate management, controls and export via a multi-phase (2 phase) trunkline to shore. Compression facilities provided by an adjacent platform installed in a later phase or as a module installed onto the initial platform.
- Theme B – subsea tieback to a fixed platform on the continental shelf providing gas separation (free water knock out), water treatment, hydrate management, controls and export via a multi-phase (3 phase) trunkline to shore. Compression facilities provided by an adjacent platform installed in a later phase, or as a module installed onto the first platform.
- Theme C – subsea tieback to a riser platform providing controls, flowline and trunkline pigging and trunkline pressure protection, with a multi-phase (3 phase) trunkline to shore. Compression facilities are provided by an adjacent platform installed in a later phase.
- Theme D – subsea tieback to floating facility located over the field or continental slope region (for example, semi-submersible or tension-leg platform), providing gas separation and/or dehydration, water treatment, hydrate management, controls and export via a multi-phase trunkline to shore. Compression facilities provided later by a fixed platform on the continental shelf, tied in to the trunkline, or by an additional floating platform either in a deepwater or shelf location.

- Theme E – tension-leg or spar wellhead platform located over field, providing gas separation and /or dehydration, water treatment and export via a multi-phase trunkline up the continental slope and to shore. Compression facilities provided by a fixed platform on the continental shelf tied in to the trunkline, or alternatively by an additional floating facility.

Example graphics illustrating a particular concept within each of the above themes is presented in **Figure 3-4**.

3.3.1 Initial Screening

Three of the above themes (A, D and E) were eliminated from further consideration during the initial screening process using selection criteria comprising:

- health and safety, operability
- resource recovery
- execution
- strategic (aggregation potential)
- economic.

A large dehydration platform (Theme A) was discounted for a number of reasons. Firstly it would involve high operational complexity and a significant offshore manning requirement. This increases the overall level of risk to personnel as well as impacting upon reliability and operability.

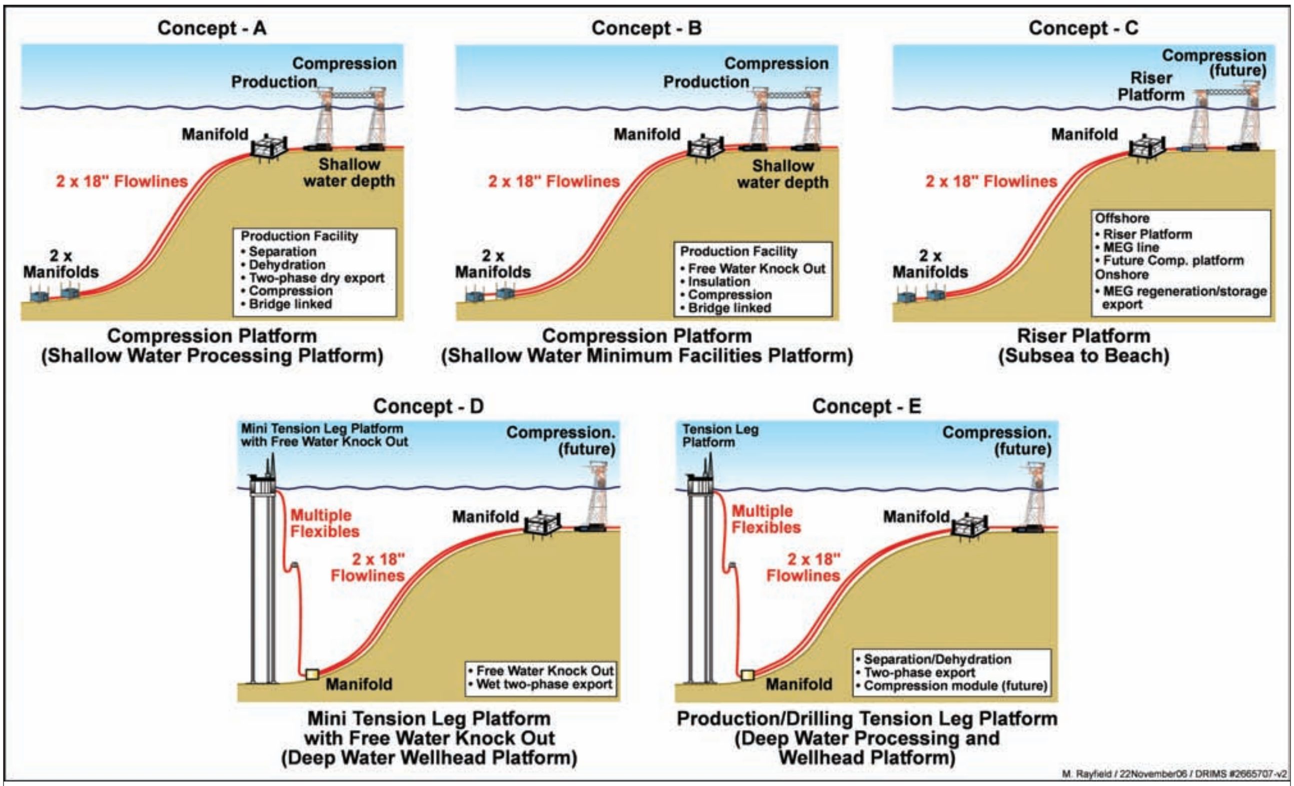
Furthermore, designing and building a facility with the ability to provide gas dehydration, water treatment, hydrate management, controls and export would be a very large and complex undertaking. Based on initial studies, it was expected that the required offshore facility would have an operating topsides weight of 20 000 tonnes or more. This was considered to lead to significant schedule risk for the design, construction and installation phases of the Development. Although it is assumed that a relatively large compression platform will be required later in the life of the Development, the delay until compression will allow the required investigation and design to take place.

Lastly, the selection of a dry (2 phase) trunkline would restrict third-party tie-in options because gas would need to be fully dehydrated before tying into the gas trunkline for processing at the onshore gas processing plant. This would necessitate separate dehydration facilities or flowlines back to the Pluto platform.

Similarly concepts within themes D and E (floating or tension-leg/spar wellhead platform) potentially lead to more complex aggregation of gas resources from other discoveries and prospects in the region. This is due to the increased complexity of installing additional risers on floating platforms as well as flow assurance problems caused by routing flowlines from shallower water fields down the continental slope to the platform at the Pluto gas field. The selection of a floating platform, particularly a tension-leg supported structure, reduces the flexibility to increase processing functionality and topsides weight. This potentially increases the additional processing or flow assurance facilities needed by aggregated fields.

The removal of all full offshore processing options effectively leads to the selection of a non dehydrated (or wet) trunkline.

Figure 3-4 Example Concepts for Each Offshore Development Theme



3.3.2 Detailed Comparison and Selection

After eliminating themes A, D and E, more detailed engineering and economic evaluation was undertaken for the remaining two themes. This helped identify a reference case option for final selection within each theme. This approach is illustrated in **Figure 3-5**.

The reference cases for this comparison were subsea wells tied-back to a minimum facilities platform (Theme B) or riser platform (Theme C) on the continental shelf. The minimum facilities platform would provide gas/water separation, water treatment and disposal of produced formation water overboard, as well as controls and power for the subsea production equipment. A riser platform would provide pressure protection for the pipeline, power and controls to the subsea systems, and tie-in facilities for to the Pluto gas trunkline and to future compression facilities.

The reference case options for both themes assume that a future compression platform will be required, adjacent and bridge-linked to the initial platform.

The final selected theme was subsea wells tied-back to riser platform, with hydrate management by Monoethylene Glycol (MEG), with an onshore MEG regeneration unit.

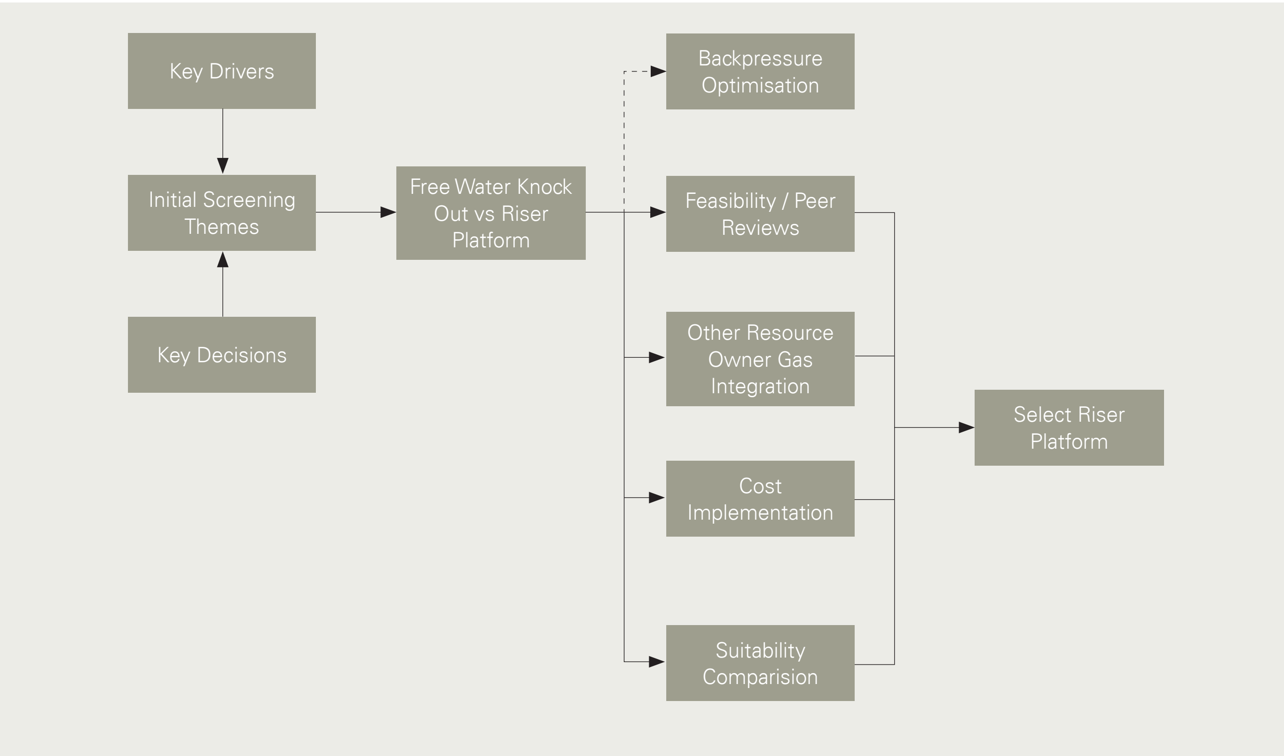
Although the costs for the riser platform were consistently lower than for the minimum facilities platform, the difference between the two was well below the level of cost estimating accuracy; therefore, cost was not considered to be a differentiating factor.

The lower scope and complexity of the riser platform presents lower schedule risk. The minimum facilities platform concept involves greater complexity and requirement for active intervention on shutdowns. The riser platform, on the other hand, involves much less processing equipment and no requirement for active intervention, but production depends on the continuous operation of the MEG regeneration unit. However, MEG as a flowline hydrate management strategy does have other advantages including assisting with corrosion management for carbon steel flowlines and providing hydrate management in the trunkline.

The riser platform concept provides greater flexibility and greater tie-back range for the aggregation of area resources. Additionally, it was believed that a MEG-based flow assurance strategy would be more acceptable to nearby resource owners.

Although in the initial phase of development the riser platform option does not provide for offshore water disposal, the selection of a MEG regeneration system for hydrate management significantly limits the volume of formation water that the system can produce, as the water volume in the system drives the volume of MEG required and therefore the capacity of the regeneration system. Therefore the Pluto offshore system cannot feasibly produce significant volumes of formation water prior to the installation of the offshore compression facility.

Figure 3-5 Summary of Offshore Concept Selection Process



3.4 Offshore Trunkline Route

3.4.1 Overview

The selection of a suitable trunkline route between the Pluto gas field and the Burrup Peninsula is based on a range of factors including seabed bathymetry, metocean conditions, geophysical and geotechnical conditions, trunkline length (cost), impacts on existing user groups (for example, fisheries, shipping lanes) and environmental considerations.

There is an extensive dataset of information relating to the selection of trunkline shore approaches on the Burrup Peninsula. This work was conducted primarily for the North West Shelf Venture (NWSV) second trunkline from the North Rankin A platform to the existing NWSV Karratha Gas Plant located on the Burrup Peninsula (Woodside 2006b). Many of the conclusions drawn from previous studies remain valid today. A desk-top study was therefore undertaken to assess each route option for the Pluto LNG Development.

The following four trunkline routes have been considered to date (**Figure 3-6**):

- Option A – via Mermaid Sound with a landfall at the NWSV Karratha Gas Plant (Option 1) or via Mermaid Sound with a landfall at Holden Point (Option 2)
- Option B – via Mermaid Strait with a landfall along the north-eastern coastline of West Intercourse Island
- Option C – via Nickol Bay with a landfall near Cowrie Cove
- Option D – via Mermaid Sound with a landfall at Conzinc South.

Option A is the preferred gas trunkline route. Although engineering work is not progressing on Option B, this option has not been eliminated and is to be maintained as a potential fallback option if route Option A is not deemed technically feasible. The exact landfall location (Option 1 or 2) is still being evaluated and is discussed further in **Section 4**. The routes eliminated from further assessment (Options C and D) and the reasons why they were discounted are outlined below.

3.4.2 Option C

Option C would involve the construction of an offshore trunkline around the Dampier Archipelago and through Nickol Bay. This option was initially considered to support development at Site E on the eastern side of the Burrup Peninsula. This option was eliminated from further consideration because of the costs associated with the longer trunkline length. Potential for disruption to existing user groups, including recreational and commercial fisheries operating within Nickol Bay, and location of the shore crossing within the Burrup Peninsula Conservation Reserve was also taken into consideration.

3.4.3 Option D

Option D would require installation of a trunkline through Mermaid Sound prior to landfall at Conzinc South. The shore crossing location at Conzinc South exhibits steep terrain, making it problematic to construct the nearshore and onshore section of the trunkline route.

3.5 Onshore Trunkline Route

As stated previously in **Section 3.4.1**, Option A is the preferred gas trunkline route and is further discussed in **Section 4**. Although engineering work is not progressing on Option B, it has not been eliminated and is to be maintained as a potential fallback alternative if Option A is not deemed technically feasible. A southerly deviation to route Option B was also considered. The southerly deviation would have bordered the Dampier Salt operations on the southern Burrup Peninsula and was discounted due to construction constraints such as poor access and difficult terrain (**Figure 3-7**). Furthermore, the route that follows the southerly deviation was longer than other options and therefore not considered to be the most cost effective route.

3.6 Waste Water Management Concept

A riser platform concept, with MEG hydrate inhibition, necessitates management of produced water onshore as both formation and condensed water streams will flow to shore with the Pluto gas field reservoir fluids. The process and volumes are described in **Section 4.7.5**. In addition, the facilities will generate other sources of water that require treatment and disposal from site. These sources include sewage, greywater, non routine contaminated water, accidentally oily contaminated water (AOC water) and demineralised water.

Stormwater and clean water runoff from hardstand areas around facilities and roads will be directed into local drainage lines, as described in **Section 4.7.6**.

Discharge of treated water to Mermaid Sound, via a short ocean outfall, has been included within the Pluto LNG Development reference case. Although this option forms the reference case, alternative to discharging treated water to Mermaid Sound are being investigated and are being considered in the context of the Environmental Quality Management Framework for Mermaid Sound (DOE 2006a). Produced water has traditionally been considered a waste product of hydrocarbon production; however, given the scarcity of fresh water in the Pilbara region, options to re-use water are preferred by Woodside over disposal to sea. The impacts of discharging waste water are discussed in **Section 7.8.13**.

A concept selection process has been undertaken to identify alternative management approaches to the reference case. Alternatives were identified by consultation with surrounding land users, stakeholders and internally. A range of potential options was identified and a preliminary screening process was undertaken to remove options with fatal flaws (that is, flaws which, by themselves, dismissed an option from further consideration).

Initial screening in this manner eliminated a number of options from consideration, namely:

- Re-injection back into the reservoir, which would necessitate significant capital investment in a return pipeline from the onshore facilities to the wellheads, large compressor pumps and use of additional chemical inhibition.
- Injection onshore, discounted primarily based on there being little evidence available to suggest that a suitable aquifer could be identified that would be hydraulically sealed from the larger groundwater system.
- A long ocean outfall, as this option would again require additional capital expenditure on a pipeline and continual dosing of the waste water with biocides and corrosion inhibitors to protect the pipeline, which would be continuously discharged offshore.
- Potable water use, based on an expectation that it would prove difficult to find users for the water produced that were accepting of its origin (regardless of treatment levels or assurance processes in place).

Remaining options were then screened, using the Development reference case (a nearshore outfall, disposing of highly treated produced water to Mermaid Sound) as a comparison. The outcomes of the screening process are summarised in **Table 3-5**.

Constraints which would need to be overcome if one (or a combination of the options) is to be implemented include the technical feasibility of treatment to required levels and guaranteeing demand (or providing suitable buffer storage) for the water generated.

These options will be further considered throughout the detailed design phase. If technical, commercial and regulatory criteria can be met, part or all of the waste water generated by the Development may be utilised onshore within one or more of the above uses.

Consideration of co-mingling treated water via existing waste water outfall infrastructure has also been considered conceptually. Several effluent disposal lines exist within proximity to the Pluto LNG Development, including a multi-user brine disposal line from the local desalination plant servicing Burrup Fertiliser's Ammonia Plant, as well as a sewage disposal line for the NWSV Karratha Gas Plant. Whilst conceptually this would limit the number of mixing zones located within Mermaid Sound, the addition of treated water from the Development would result in an increase to the area of that mixing zone and would add further to contaminant concentrations within these mixing zones. A multi-user system also presents some potential risk stemming from combining waste streams that are not generated by one user and limits the potential for Woodside to test the modelling and assumptions made in the Draft PER. In addition, infrastructure (for example, pipeline connections) would be required to implement this concept, whereas the reference case option of the jetty disposal pipeline requires negligible additional infrastructure.

Table 3-5 Screening Process Outcomes for Wastewater Management Options

Option Considered	Outcome of Screening
Nearshore discharge (reference case)	Basis of Development approval application.
Use within the gas processing plant for service water	Taken forward for detailed consideration. Subject to technical feasibility of treatment levels required.
Use within the NWSV Karratha Gas Plant for service water	Taken forward for detailed consideration. Subject to technical feasibility of treatment levels required, commercial consideration and additional regulatory approvals for interconnections.
Combined (or stand alone) wetlands/ heritage walk	Not taken forward. Requires additional land, when the Development has actively sought to minimise its disturbance footprint.
Use by external parties for non-potable uses (for example, dust suppression)	Taken forward for detailed consideration. Subject to commercial consideration and additional regulatory approvals for interconnections.
Use as an irrigation supply	Not taken forward. Requires development of infrastructure and agricultural activities not currently supported on the Burrup Peninsula, with supply dropping after installation of a second platform.

3.7 No Development Option

Should the Development not proceed, both direct and indirect economic investment would be lost throughout the construction and operational phases of the Development. Failure to develop the Pluto gas field will result in missed opportunity in terms of economic development and subsequent loss of an estimated A$29 billion in Gross State Product to Western Australia and direct combined revenue to the Commonwealth and state in the order of A$6 billion over the life of the Development.

Figure 3-6 Alternative Trunkline Route Options

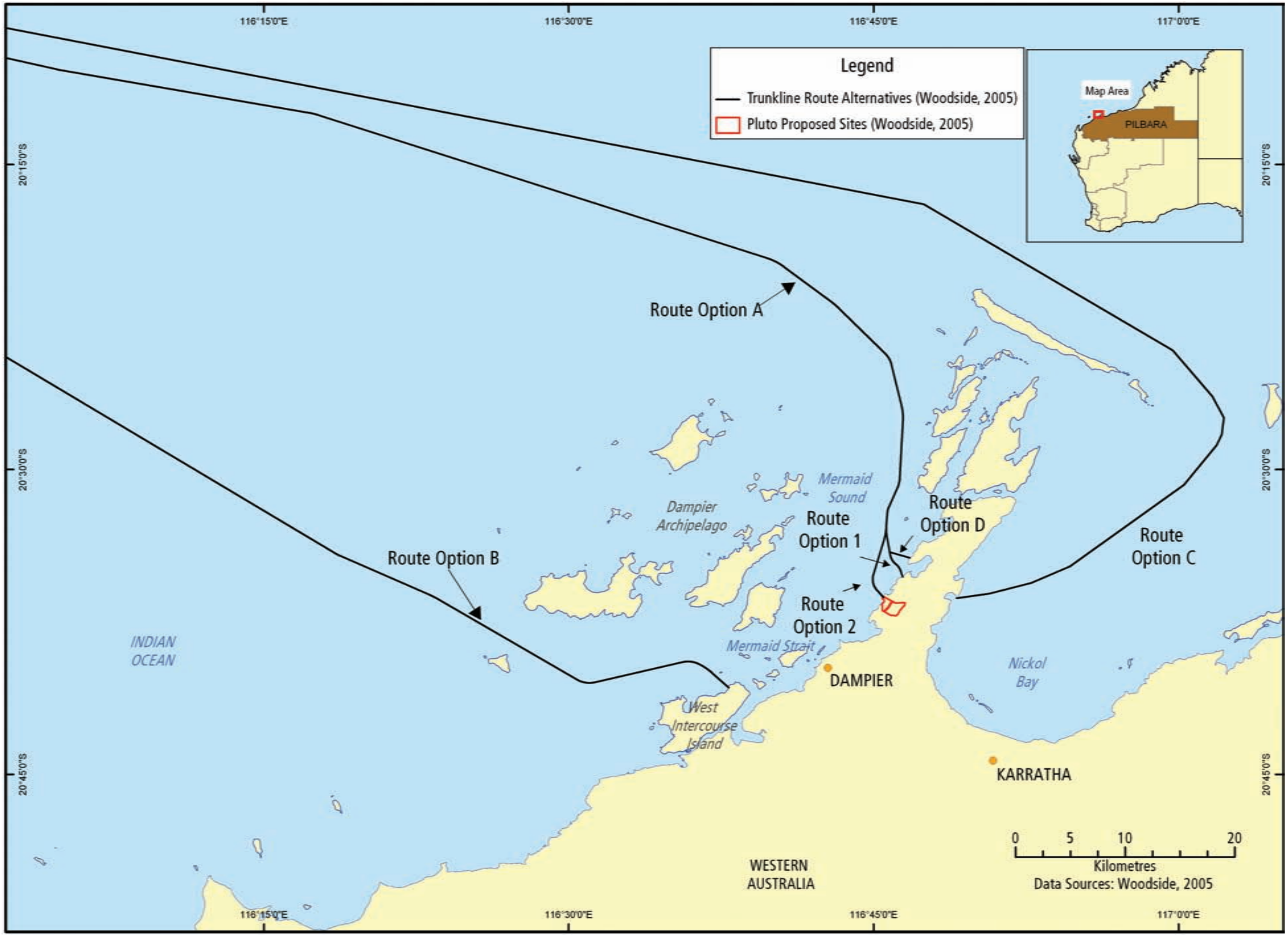
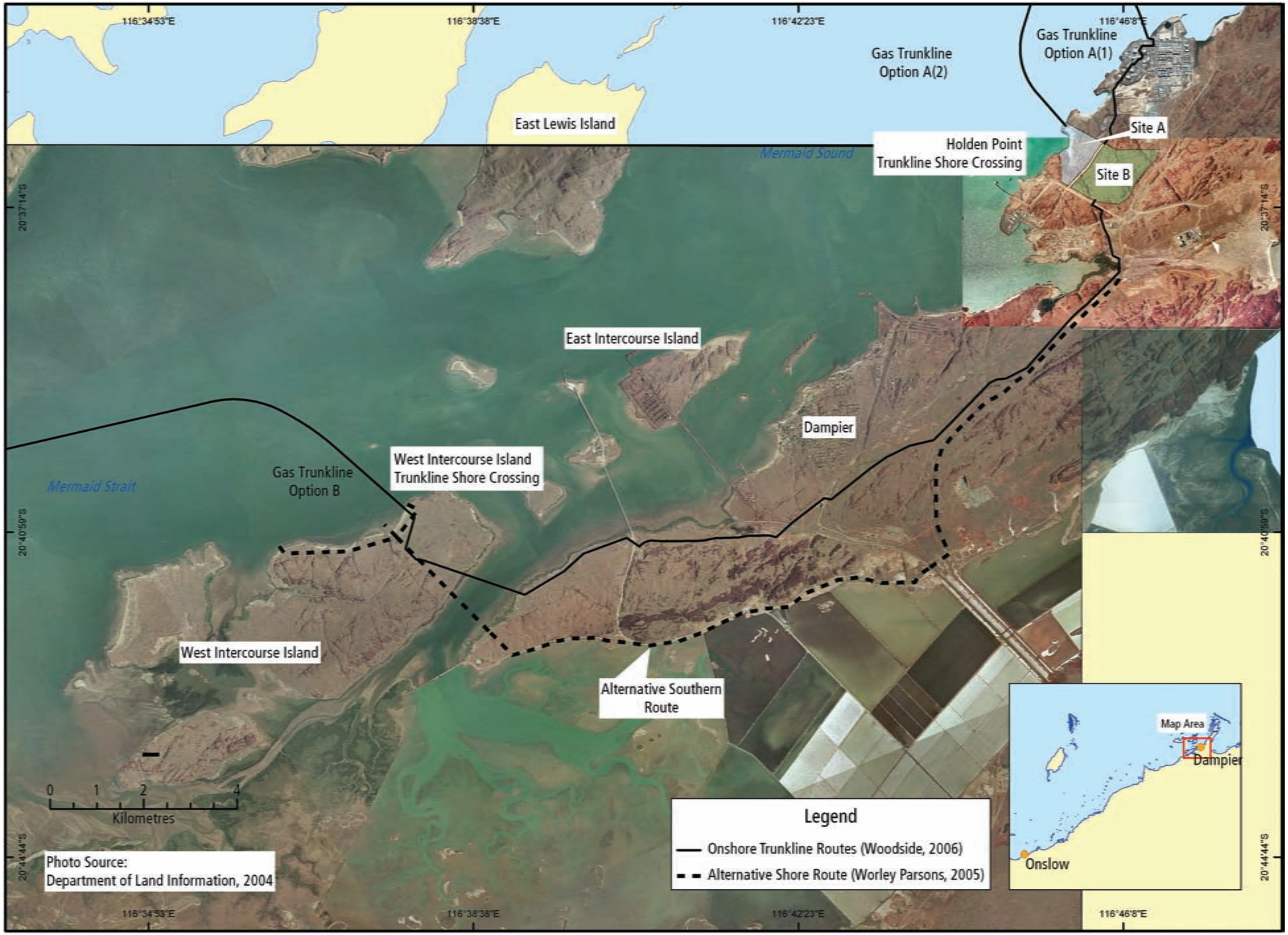


Figure 3-7 Alternative Onshore Trunkline Routes Considered



Development Description 4

4.1 Pluto LNG Development Overview

The Pluto gas field was discovered in April 2005 in the North-West Shelf area. The field is located approximately 190 km from the Burrup Peninsula, 100 km from the coast of Western Australia and approximately 50 km north of the Montebello Islands (**Figure 4-1**). The Pluto gas field is located in permit WA-350-P on the continental slope in water depths of 400–1000 m (**Figure 4-2**).

Three appraisal wells have been drilled to date and initial interpretation of seismic data and drilling results suggests that the Pluto gas field contains a Contingent Resource of approximately 116 000 million m^3 (Mm^3), equivalent to about 4.1 tcf of Dry Gas and approximately 42 million barrels (mmbbls) of condensate. Further exploration prospects within WA-350-P and neighbouring permits will potentially be developed, if commercial discoveries result.

The Pluto LNG Development will comprise two onshore processing trains each with a maximum production capacity of up to 5.9 Mtpa of LNG, or a total capacity of approximately 12 Mtpa located on the Burrup Peninsula (**Figure 4-3**). Detailed layouts of Site A and Site B are provided later in **Section 4.7.2.2**. An expansion of production capacity, which involves the construction of one or more additional LNG trains, is possible but timing (should the expansion eventuate) will be dependent on market and supply variables and hence is not considered as part of this Draft PER.

Offshore development drilling for the Pluto gas field will be staged, commencing initially with three to seven wells and up to 12 wells in total as the field matures. The final well numbers will depend on well design and performance. As the field reaches maturity, some wells will be abandoned and additional wells (re-drills) may be required at that time, these would be tied–back into the existing manifold system.

Wellstream products will be delivered to an unmanned offshore riser platform located in a water depth of 80–85 m via two manifolds and flowlines. The riser platform will not support any processing facilities but will be equipped with control systems. It is likely that gas compression facilities will need to be installed after 4–10 years of operation as the reservoir pressure declines. The gas compression facilities will be installed on an additional platform located adjacent to the riser platform and linked to the riser platform. This platform is likely to be manned during normal operations and, in addition to compression facilities, will remove a portion of the produced water from the wellstream gas and liquids transferred into the trunkline.

Wellstream gas and liquids from the riser platform, including produced water (that is, a combination of formation water and condensed water) will be transferred via a subsea gas trunkline from the riser platform to shore for treatment in the initial years of operation. Formation water is the water generated along with the gas and condensate from the reservoir during wellstream extraction. However, condensed water will also be produced as water drops out of the gas during transport to shore. The onshore gas processing plant will therefore receive a combination of natural gas, condensate, formation water and condensed water.

Once received at the onshore gas processing plant, located at Site B on the Burrup Peninsula, the gas, condensate and other liquids will be separated. The formation and condensed water will be treated to remove contaminants and then discharged into Mermaid Sound via a pipeline discharging at the end of the export jetty. The gas will be processed into LNG, and the LNG and condensate will be piped from Site B to storage and export facilities to be located at Site A. Tankers will then load and export the final product from Site A via a purpose-built jetty and navigation channel. The gas processing plant is being designed to potentially cater for Domgas supply, should favourable market conditions eventuate. The Domgas plant will have a capacity to deal with up to 3.5 to 4 Mtpa of gas, however, this capacity will be refined at a later stage.

A marine supply base and a helicopter operations base will be required to service the needs of the Development and it is expected that such facilities will be used by multiple operators. It is uncertain whether this will be constructed by Woodside or a third party. Environmental approvals for the construction and operation of a marine supply base and a helicopter operations base are outside the scope of this Draft PER.

The Pluto gas field and associated offshore and onshore facilities are anticipated to have a design life of up to 30 years. The key characteristics of the proposed Pluto LNG Development are outlined in **Table 4-1**. The boundary locations of the Pluto gas field, Site B and Site A are presented in **Table 4-2**.

4.2 Preliminary Development Schedule

The key milestones for the project schedule are shown in **Figure 4-4**. The schedule covers an overall period of approximately 54 months from commencement of Front End Engineering and Design through to first gas, by end 2010.

Table 4-1 Key Characteristics of the Pluto LNG Development

Criteria	Key Characteristics of the Pluto LNG Development
Hydrocarbon resource size	Approximately 116 000 Mm^3 (4.1 tcf) – recoverable Dry Gas Approximately 6.7 Mm^3 (42 mmbbl) – recoverable condensate
Proposed number of wells	Up to 7 wells in 2008 Up to 12 wells in total
Subsea infrastructure	Two manifolds with dual flowlines
Offshore platform	Unmanned riser platform located in 80–85 m water depth
Offshore gas trunkline	A 762–1068 mm (30–42") carbon steel trunkline A 188 km length offshore trunkline from platform through Mermaid Sound. Two deviations within Mermaid Sound are under consideration: • Option 1: trunkline landfall at Karratha Gas Plant • Option 2: trunkline landfall at Site A near Holden Point.
Onshore gas trunkline	Trunkline from landfall to processing plant located at Site B, Burrup Peninsula
Onshore gas processing plant (Site B)	Up to 12 Mtpa
Gas storage and export facilities (Site A)	2 x 160 000 m^3 LNG cryogenic tanks 2–3 condensate tanks with a combined capacity of up to 130 000 m^3
Marine facilities	An export jetty and causeway Approximately 10 km long navigation channel, turning basin and berth pocket Dredge spoil disposal grounds at the existing spoil ground A/B, a northerly extension of this ground and to a deep water site (2b) near the northern limits of the Dampier Port waters. Treated waste water discharge pipeline terminating at the end of the export jetty
First gas	End 2010
Design life	Up to 30 years

Table 4-2 Pluto LNG Development Boundary Coordinates

Eastings	Northings	Site/Location
309 186 mE	7 807 305 mN	Pluto Gas Field North-West Boundary
316 134 mE	7 806 343 mN	Pluto Gas Field North-East Boundary
307 422 mE	7 789 881 mN	Pluto Gas Field South-East Boundary
303 788 mE	7 789 774 mN	Pluto Gas Field South-West Boundary
329 026 mE	7 788 215 mN	Platform Location Centre Point
476 655 mE	7 721 063 mN	Site B North-East Boundary
475 575 mE	7 721 184 mN	Site B North-West Boundary
474 877 mE	7 720 258 mN	Site B South-West Boundary
475 867 mE	7 719 893 mN	Site B South-East Boundary
475 526.1 mE	7 721 27.1 mN	Site A North-East Boundary
474 770.7 mE	7 721 639.8 mN	Site A North-West Boundary
474 824.4 mE	7 720 289.1 mN	Site A Southern Boundary
474 638.3 mE	7 720 985.5 mN	Site A Southern Boundary

Coordinates datum: WGS94

4.3 Pluto Gas Composition

As shown in **Table 4-3**, preliminary interpretation indicates that Pluto gas has a relatively low CO_2 content (approximately 2%) compared to other gas fields in the region. The Pluto gas field reservoirs contain extremely low concentrations (below detection level) of hydrogen sulphide (H_2S).

Table 4-3 Pluto Wet Gas Composition

Component	Average Mol %
Hydrogen sulphide	0#
Carbon dioxide	2
Nitrogen	8
Methane	83
Ethane	4
Propane	<2
Ethane	4

Note: # Below detection levels of 0.5 ppm

4.4 Development Drilling

The initial three to seven wells will be drilled over an approximate 10 month period, with drilling commencing in mid 2008. It is anticipated that a maximum of 12 wells will be drilled in total.

All wells for the Development will be drilled using either an anchored semi-submersible drilling rig or a dynamically positioned drill rig (that is, no anchors). A semi-submersible drill rig is shown in **Figure 4-5**. This rig has accommodation for up to 120 personnel.

During rig move and anchoring operations (assuming the rig is not dynamically positioned) the rig is likely to be supported by up to three anchor handling/supply vessels. During drilling, the rig will be supported by two supply vessels, with one in attendance at the field at all times.

The wells will be drilled using Water Based Muds (WBMs) for the top hole sections and either WBMs or Non-Water Based Muds (NWBMs) for the lower sections. The selection of mud types is dependant on technical aspects of the drilling programme that will not be known until completion of detailed design.

Results from appraisal drilling in the Pluto gas field indicate that scale management will not be a significant issue for the production wells. Given that the reservoir rock is unconsolidated, down hole sand control will be required. Well management strategies will be developed throughout the field life.

Figure 4-1 Pluto Gas Field Location

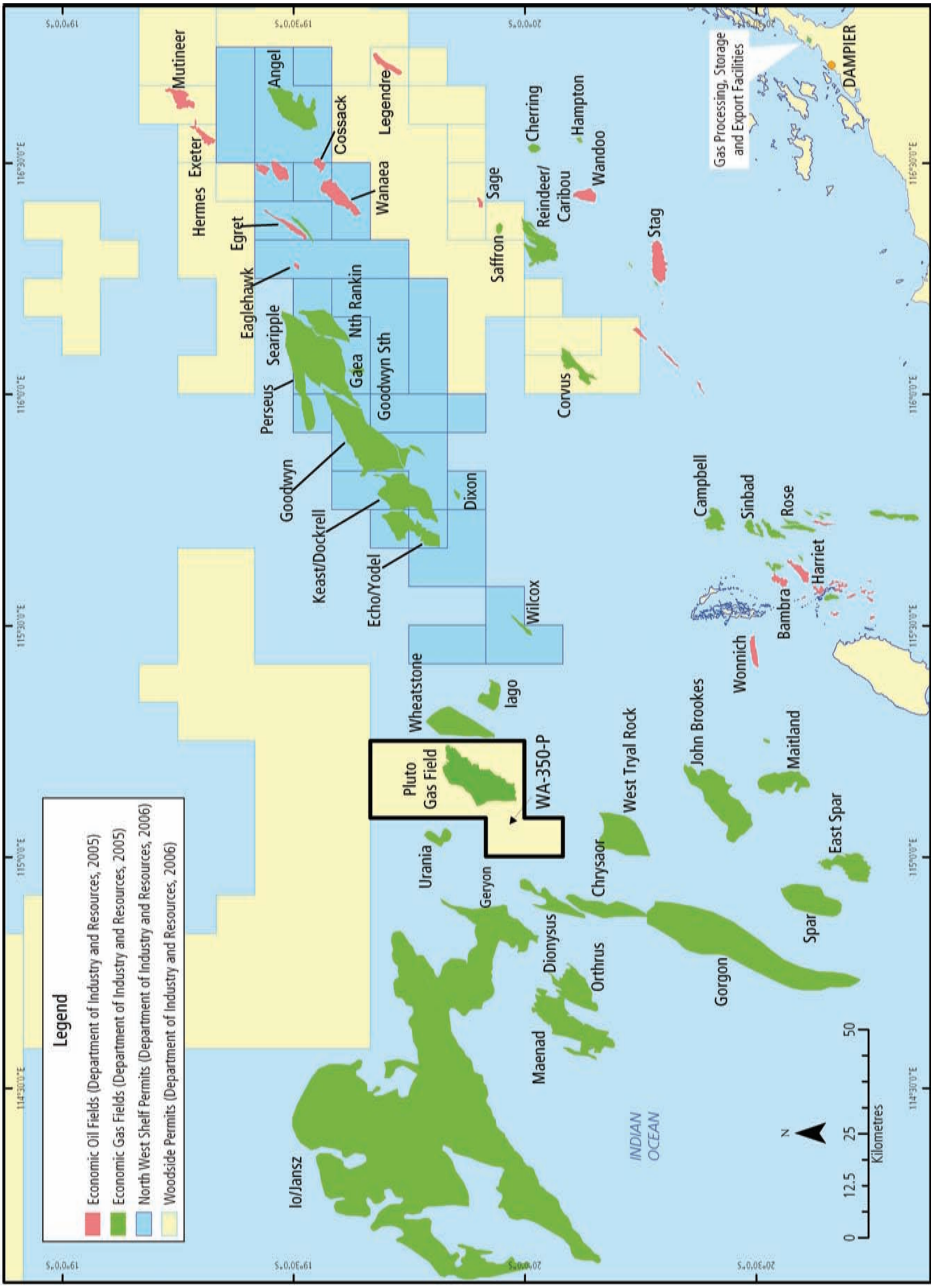


Figure 4-2 Pluto Reference Case Development

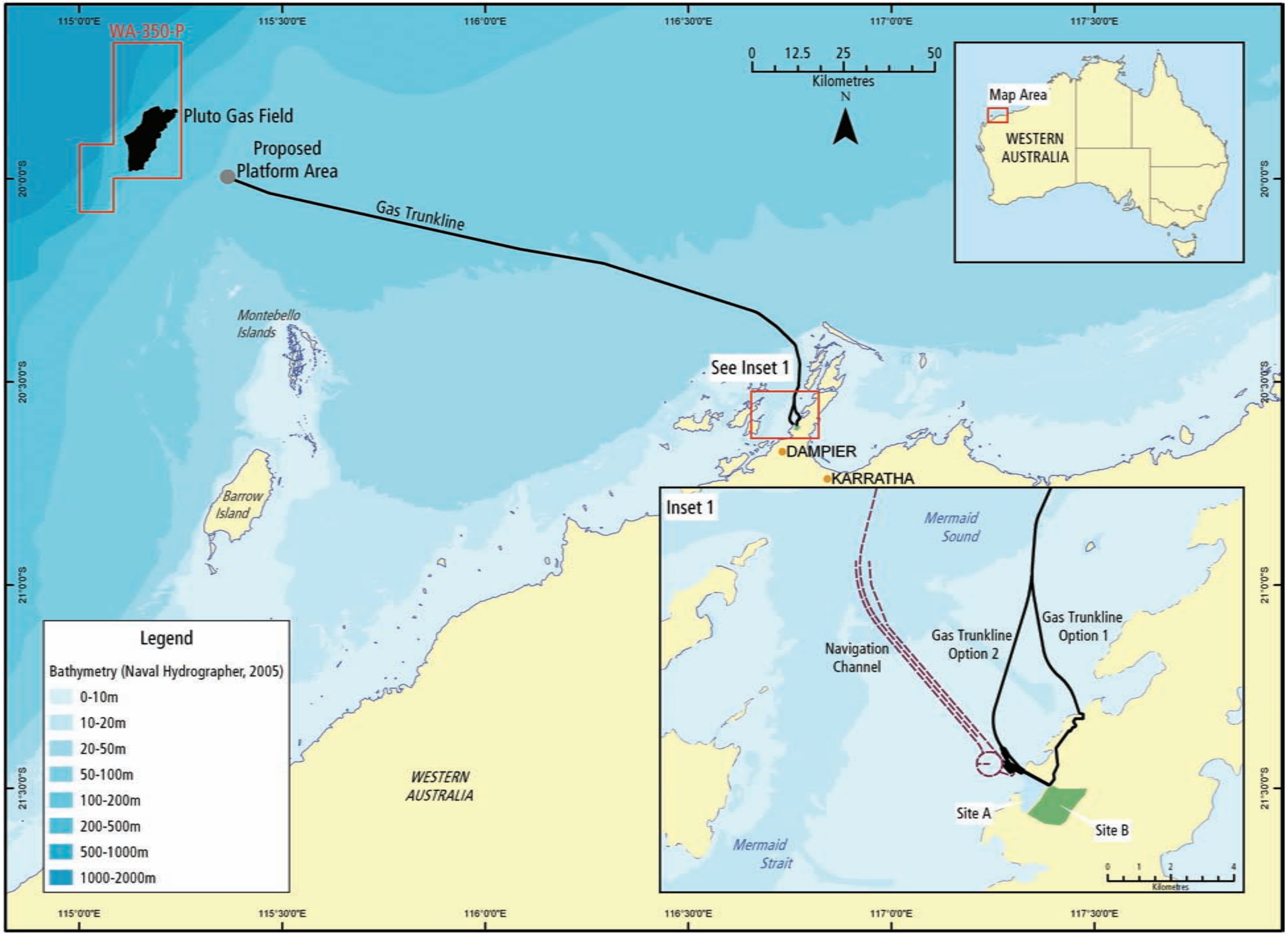


Figure 4-3 Detailed Location of Burrup Peninsula Project Area

Figure 4-4 Preliminary Development Schedule

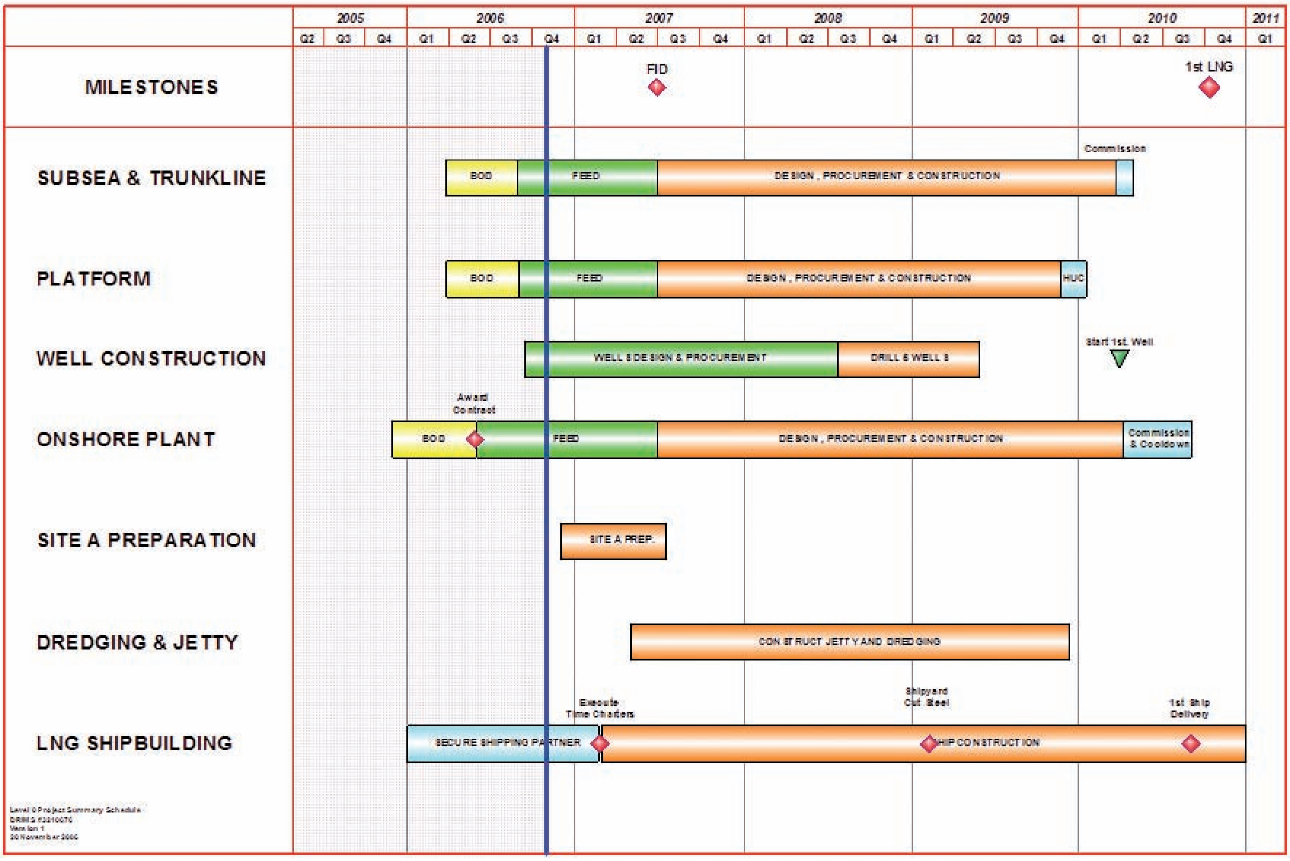


Figure 4-5 Semi-Submersible Drill Rig

4.5 Offshore Development

The function of the offshore development will be to extract gas and condensate from the Pluto gas field and deliver these hydrocarbons to the onshore gas processing plant via a gas trunkline. The offshore development can be broadly divided into subsea wells and installations (for example, the manifolds and flowlines), a riser platform, a gas trunkline and, after 4–10 years of operation, a second platform. The design of the offshore facilities will incorporate elements to allow the introduction of other fields into the production system.

4.5.1 Subsea Wells and Installations

The location of wells and associated subsea facilities will be influenced by reservoir targets, general bathymetry, seabed features and hydraulic performance of subsea production systems.

Subsea installation activities will be conducted from specialist surface vessels, which will control Remotely Operated Vehicles (ROVs). The ROVs will be used for activities such as installing the manifolds and hooking up flowlines.

The development plan is for two subsea manifolds to be installed from a single drill centre with the capacity to tie-back a number of subsea wells. The manifolds will consist of heavy duty systems of valves and pipes to control the flow of reservoir fluid from the well to the production flowlines. The production flowlines will include two flowlines from each manifold, constructed of either carbon steel or corrosion resistant alloy. The flowlines will carry liquids (comprising small volumes of produced water and condensate) from the wells to a platform via risers, which are flexible pipes rising from the seabed to the platform. The flowlines will run from the manifolds to the platform. There may be a requirement for further flowlines at a later stage.

The produced water carried from the wells to the platform via risers will include condensed water and formation water. Condensed water is water condensed from the gas phase and is normally fresh water. Further investigation is required during detailed design to determine whether in practice it contains some low levels of dissolved hydrocarbons and salts. The condensed water rate will increase over time as the reservoir pressure falls. Formation water is the saline water from the Pluto reservoir. The Pluto gas field will be managed to avoid large quantities of formation water. It is conservatively assumed that 20% of the produced water is formation water and the remainder is condensed water.

Due to the deep water and cold temperatures encountered at the Pluto gas field, hydrate formation in the flowlines will need to be managed. Natural gas combined with produced water can form hydrate plugs under low temperature and high pressure. The formation of hydrates in the flowlines can be prevented with a combination of chemical treatment and/or thermal insulation of the flowlines (to keep temperature high enough to prevent plugs forming). A MEG re-circulation system has been selected to manage hydrates (**Section 4.7.5**).

4.5.2 Offshore Platform

4.5.2.1 Overview

The riser platform will be located in relatively shallow water between 80 m and 85 m water depth (**Figure 4-6**). In this range of water depths the platform substructure will be fixed to the seabed, and be of the 'fixed jacket' type. Investigations are ongoing to determine the exact final positioning. The substructure of the platform will consist of a four leg jacket secured to the seabed. The jacket will safely support the platform topsides, which are expected to be in the range of 1000 to 3000 tonnes dry weight and will be located within the area shown on **Figure 4-2**. It is anticipated that the riser platform will not normally be manned, although facilities for manned operation would be provided. A second platform will be installed at a later stage to house compression facilities; environmental approvals for the second platform are outside the scope of this Draft PER and will be sought separately.

No produced water will be discharged at the riser platform in the initial years of operation. During this time, all produced water will be directed from the platform through the trunkline. Produced water carried from the platform to the onshore gas processing plant will include formation water, condensed water and additives such as MEG. Separation of gas from liquids will occur onshore at the gas processing plant and disposal of treated waste water, including formation water and condensed water, will occur in nearshore waters.

Following construction of the second compression platform, the wellstream gas and liquids will be transferred from the riser platform to the second platform for partial produced water removal. Produced water removed will be discharged to sea from the second platform. Following removal of produced water, the gas, condensate and residual produced water will be transferred from the second platform via the trunkline to the onshore gas processing plant.

4.5.2.2 Riser Platform

The riser platform will likely include utilities as described below.

Power Generation and Distribution: Power generation is likely to be supplied by gas turbine driven generators that have the capacity to use diesel if gas is not available (such as during start-up operations). The need for separate emergency power generation equipment will be determined during the detailed design phase.

Fuel Gas Treatment: Gas would be the main source of fuel for power generation. A fuel gas treatment system usually consists of pressure reduction, filtering, dew pointing and metering equipment prior to use by turbines and other fuel gas users.

Diesel System: A diesel storage and distribution system may be required to provide a fuel source for emergency power generation systems, materials handling cranes, firewater pumps, and as a back up fuel source for the main power generation system. Diesel would be transported to the platform by supply vessel.

Material Storage: A wide variety of chemicals and other materials may be stored and used on the platform including the following:

- acids and solvents
- hydrate and corrosion inhibitors
- surface active agents
- lubricating fluids and greases
- hydraulic oils and fluids
- paints
- specialised cleaning fluids
- seawater system treatment chemicals.

Emergency Flare System: An emergency depressuring (flare) system, also referred to as a 'safety flare system', will be provided. The safety flare will be designed to provide a safe means of rapidly disposing pressurised gas from process equipment in the event of an emergency or process upset. The flare system is also required during commissioning, initial production, process shutdowns and restarts, maintenance, and equipment downtime. A pilot flare will keep the emergency flare lit.

Chemical Storage and Injection Facilities: Chemicals may need to be stored on the platform for injection into the subsea systems (flowlines/wellheads/manifolds) and trunkline and for production purposes at the platform.

Figure 4-6 Development Concept

Hydrate inhibition in the flowlines and trunkline will involve the injection of MEG at the subsea manifolds. The MEG will travel through the flowlines to the platform and on through the trunkline to the gas processing plant. A MEG regeneration facility, located at the onshore gas processing plant, will continuously recover the MEG and recirculate it to the offshore platform by means of a dedicated pipeline (**Section 4.7.5**). The MEG pipeline will follow the main gas trunkline in parallel.

Subsea Controls Support System: The subsea equipment will be controlled by an electro-hydraulic system. The hydraulic fluid, power and controls communications functions will be transported to the manifolds via an umbilical. In addition, this umbilical may also transport some of the production chemicals required at the field. The platform will house all of the equipment necessary to support these functions including a hydraulic pressure maintenance system, power supply and uninterrupted power supply system, a master controls station and the umbilical initiation point.

Seawater Treatment: Seawater may be required for various purposes, including cooling of wellstream fluids, process equipment, fire protection systems, and freshwater production. Seawater treatment systems may include coarse filters to strain debris from the seawater and injection of hypochlorite (or similar biocide) to prevent the build-up of marine fouling growth on the internal surfaces of the system. Hypochlorite is the most widely used material and is normally produced onboard by electrolysis of seawater.

If seawater is used for cooling purposes it will be routinely discharged overboard at a temperature less than 60°C.

Accommodation Facilities: The riser platform will not normally be manned during operation. Accommodation facilities may be provided for occasions where short-term stays are necessitated. Sewage and grey water will be macerated to a size less than 25 mm prior to discharge to ocean. No sewage or putrescible waste will be discharged within 12 nm of land.

Safety Systems: Safety systems will include escape equipment, fire/gas/smoke detection and protection systems, and back-up power systems. The fire protection system will consist of passive systems (such as equipment coatings) and active systems possibly including deluge, water, foam, CO_2 and extinguishers. The most appropriate system for each area will be selected based on detailed risk assessments. Ozone-depleting substances will not be used for these systems. Safety equipment including fire pumps, emergency lighting and communications equipment, are generally designed to be completely independent and with appropriate levels of redundancy. Independent fuel or energy sources, such as diesel, may be used.

Communication Systems: Standard offshore communications systems will be in place. Additional safeguards will also be implemented such as the gazetting of the platform onto navigational charts and the creation of a safety exclusion zone.

Flowline and Trunkline Pigging Facilities: For operational and inspection reasons, it may be necessary to run 'pigs' through the flowlines and / or trunkline. The platform may include launchers / receivers for these activities.

Drains: The platform drainage and disposal systems will include closed drains, open drains and liquid hydrocarbon recovery systems. Deck drainage consists mainly of deck washdown water and rainwater.

Compression Facilities: Compression facilities are likely to be installed at a later stage (4–10 years after operation commences) to maintain the gas production rate as reservoir pressure declines. There are a number of possible options for future compression facilities, the most likely being installation of a second platform to house the compression facilities. Alternative options being considered include the installation of compression facilities on the riser platform or subsea compression. Additional utilities and systems similar to those needed for the riser platform may be required to support the compression facilities.

4.5.2.3 Offshore Platform Construction

The riser platform components will be assembled and pre-commissioned as much as reasonably possible at onshore fabrication / pre-assembly sites before transportation to the offshore location via barges.

A degree of installation, construction, hookup and commissioning at the offshore riser platform location will be required before the platform is ready to commence production.

4.5.3 Subsea Trunkline

Gas, condensate and other fluids (formation water, process chemicals and condensed water) will be transported from the riser platform to an onshore gas processing plant via a subsea gas trunkline. The preliminary design characteristics for this trunkline are presented in **Table 4-4**.

The gas trunkline will operate 'wet' (that is, the liquid phase being a mixture of condensate and produced water) with chemical inhibition required to manage trunkline corrosion. There will be a need to manage hydrates in the trunkline as well as in the field flowlines and this will be done with the injection of MEG. Re-circulating MEG will be recovered onshore and returned to the offshore facility by a return pipeline, which may be in the order of 100 to 200 mm diameter.

Table 4-4 Preliminary Trunkline Design Characteristics

Trunkline diameter	762–1068 mm (30–42") (reference case 1068 mm)
Trunkline wall thickness	20–25 mm
Trunkline material	Carbon steel (in compliance with OS F101 Gr 450)
Concrete weight coating thickness	65–100 mm
Concrete weight coating density	Approximately 3000 kg per m^3

4.5.3.1 Gas Trunkline Route

The proposed offshore gas trunkline route is presented in **Figure 4-2** and is approximately 180 km in length with a shore crossing at either the existing Karratha Gas Plant (Option 1) or at Site A, Holden Point (Option 2).

From the offshore platform, the route crosses the 50 m bathymetric contour north-west of Dampier and continues 28 km to a point where it turns to the south-east, entering the 'anchoring prohibited zone' of the Dampier Port Authority (DPA) limits. The trunkline then runs parallel (at an offset of approximately 600 m) to the NWSV existing gas trunklines. At approximately 10 m water depth, the trunkline runs between the edge of an existing spoil disposal ground and the North Rankin A trunkline. It then traverses to the south-west, almost perpendicular to the existing LNG shipping channel. Just south of the spoil ground, the route diverges as dictated by two potential landfall options:

- gas trunkline Option 1 reaches landfall at the Karratha Gas Plant
- gas trunkline Option 2 reaches landfall at Site A, Holden Point.

The gas trunkline Option 2 alignment turns back to the south-west after crossing an existing shipping channel (250 m in width) before reaching landfall at Site A. Option 1 does not cross the existing shipping channel.

4.5.3.2 Offshore Trunkline Construction

A number of trunkline construction techniques are under evaluation taking into consideration factors such as: water depth, oceanographic conditions, geotechnical characteristics, environmental sensitivities, cost and risk.

Offshore trunkline construction broadly comprises two key activities: trunkline installation and post-lay trunkline stabilisation. The exact methodology will be determined following the completion of extensive geotechnical and geophysical survey work in late 2006.

Construction of the offshore gas trunkline is anticipated to commence around April 2009. The shore approach and pre-dredge activities will commence approximately six to eight months in advance of pipelaying. It is anticipated that it will take approximately six months to lay the trunkline.

Installation Methodology: The subsea pipeline will be installed from a pipelay vessel. The pipeline is built up from nominal 12.2 m pipe lengths, each being welded to the previous section. Following completion of each weld, a Non-Destructive Examination (NDE) technique will be employed to inspect the weld, and weld repairs will be performed if required. An anti-corrosion heat shrink sleeve or cold tape will then be applied to the weld area, and the void between adjacent concrete coatings may then be filled with a suitable infill. Upon completion of this process, the pipe is laid over a pipe support ramp (stinger) on the stern of the lay barge. It is anticipated that two pipelay vessels will be mobilised for the Development. One vessel will work in the relatively shallow waters of Mermaid Sound and will also perform the shore pull. In deeper water (nominally beyond 20 m water depth) a deep water pipelay vessel will take over pipelay operations.

The deep water pipelay vessel can be either a dynamically positioned ship or a semi-submersible barge with anchors will be used as the pipelay vessel. These are large vessels, capable of laying up to 6 km of pipe per day on a 24-hour basis. Pipe sections will be delivered to the pipelay vessel using pipehaul vessels or dumb barges towed by tugs. The pipelay vessels will require a corridor up to 3000 m wide in deep waters. In these deeper waters the trunkline is likely to be surface laid on the seabed.

In shallower waters, the trunkline is likely to be laid using conventional pipelay barge techniques. An anchor–spread, shallow draft barge is likely to be required due to draught limitations of the larger pipelay vessels typically used in deeper waters. The shallow draft barge will deploy 8–10 anchors, each weighing 10–22 tonnes, around the barge to allow it to maintain its position and draw itself forward during pipelay. Anchors are continuously repositioned in sequence in front of the vessel by a number of anchor handling tugs to maintain forward propulsion. The trunkline installation vessels will require an area up to 1500 m wide (centred on route with a 600–750 m anchor spread either side of the trunkline centreline) to work within shallow water. At the shore crossing location from -5 m ACDD to 1.5 m above HAT, the construction corridor width will be narrowed to avoid coral habitat as far as reasonably practicable (**Figure 4-7**).

In shallower waters, between 50 m water depth and the trunkline shore crossing, the trunkline will be either trench and backfilled or laid on the seabed and stabilised with rock. The trunkline trench will be up to 15 m wide. The removal of unconsolidated material is likely to be undertaken using a trailer suction hopper dredge. These vessels are typically capable of loading from the seabed in water depths of 10–80 m (Woodside 2002). Consolidated material inside Mermaid Sound may be dredged using either a backhoe dredge or a cutter suction dredge. Dredged material will be placed in the designated areas as per **Table 4-9.** The operation of the dredges is discussed in **Section 4.6.5**.

Gas trunkline Option 2 will cross the existing NWSV LNG shipping channel through Mermaid Sound which is approximately 250 m wide and used to export liquids from the NWSV Karratha Gas Plant. Open cut trenching will be employed to cross the NWSV navigation channel. The open cut technique will involve excavation, pipeline installation and backfilling.

It is anticipated that the seabed in water depths from 0–5 m is comprised of igneous rock that exceeds the cutting capability of conventional dredging equipment. This rock will therefore require pre-treatment with drill and blasting techniques to ensure the construction of a suitably deep trench for trunkline stabilisation and protection. In areas beyond 5 m water depth, where a trailer suction hopper dredge cannot remove the material, or cannot manoeuvre due to the presence of the newly constructed jetty, a backhoe dredge will be required. This will be subject to detailed geotechnical investigations. A barge-mounted backhoe dredge will remove the fractured rock from the seabed into a hopper barge, moored alongside the dredge, or the material may be placed by the side of the trench.

Post-lay Stabilisation Methodology: The proposed methods for stabilising the trunkline are presented in **Table 4-5**. These methods are based on the assumption that seabed and environmental conditions are similar to those encountered for the existing NWSV trunklines; however, stabilisation of the trenched trunkline sections may vary once the geotechnical surveys have been completed and the results analysed to ensure that stability is maintained. It is anticipated that in water depths greater than 50 m out to the Pluto gas field, the trunkline will be stabilised by means of gravity anchors.

Stabilisation of the trenched trunkline sections (generally shallower water) will involve a combination of the following methods:

- *Pre-dredge and Backfill:* This method involves the dredging of a trench prior to pipelay, with backfill placed once the trunkline is installed. It is unlikely that the material which is excavated from the trunkline trench is of suitable composition to be used as backfill. The material will consist of fine, silty sediments which is prone to scouring and liquefaction. As a consequence coarser material, such as coarse sand, gravel and/or competent crushed calcarenite is required to stabilise the pipeline. This material may need to be sourced from elsewhere, for example, from a borrow area or possibly from dredging. Engineering work will be conducted during the Front End Engineering and Design phase to specify the minimum size of the particles required to stabilise the pipeline during cyclonic conditions.

- *No cover rock berm:* Beyond 8 m water depth and out to the DPA limits, the trunkline may be stabilised by means of a 'no cover' rock berm. This technique will be similar in principle to the rock dumping method described below, however, the top of the trunkline will generally have no cover (**Figure 4-8**). At intermittent sections along the trunkline, a full cover rock berm may be laid involving the dumping of larger volumes of rock to reduce the risk of the trunkline becoming destabilised during cyclone events.

- *Rock dumping:* Rock may be dumped on top of the trenched trunkline in shallow waters (**Figure 4-9**) for stabilisation and protection requirements. Fine rock will be dumped immediately around the trunkline, with a rock armour layer placed over the top. The total quantity of rock required has yet to be accurately assessed. Indications are that themaximum quantity is likely to be in the order of 660 000 m^3. This rock will likely be sourced onshore from a third party quarry. Environmental approvals, under relevant legislation, for the operation and management of quarry operations will be the responsibility of the third party proponent operating and managing the quarry and are outside the scope of this Draft PER.

- *Post lay trenching:* This stabilisation technique is applied only after the trunkline has been laid on the seabed. Methods include ploughing, mechanical trenching (using cutter wheels or chains) or jetting based tools (jet sled, mass flow excavation). These methods will minimise or negate the requirement for quarry rock backfill.

In addition, competent crushed calcarenite material excavated by the cutter suction dredge as part of the navigation channel deepening (**Section 4.6.5**) or previous dredging projects in Mermaid Sound may be suitable for re-use as trunkline backfill and cover. This option has the potential to significantly reduce the requirement for quarried rock and makes efficient use of already disturbed material and will be investigated in detail during Front End Engineering and Design.

Dredge Spoil Disposal: Sediment and spoil generated from trunkline installation activities for both the offshore (that is, beyond the DPA limits) and inshore sections of the trunkline route will require disposal. Much of the dredged material outside of the DPA limits is not likely to be suitable for backfill due to the small grain size of the material (less that 150 µm). It is therefore likely that coarse sand sourced from a pre-determined sand borrow location (yet to be identified) will be used as backfill material, where required. Preliminary estimates of dredge spoil volumes for the trunkline route are provided in **Table 4-6**. The figures presented are in-situ volumes and are indicative only with an accuracy of ±20%. Further discussion on dredge spoil disposal is provided in **Section 4.6.6**.

Table 4-5 Proposed Trunkline Stabilisation Techniques for Gas Trunkline (to 50 m Water Depth)

Trunkline Kilometre Post / Point (KP)	Approx Water Depth (m)	Proposed Stabilisation
KP 0–KP 6	0–8	Pre-dredge trench and rock dump
KP 6–KP 11	5–15	Pre-dredge trench and backfill or rock dump
KP 11–KP 18	10–20	Pre-dredge trench and backfill, or no cover rock berm or post lay trenching
KP 18–KP 24.4	10–20	Pre-dredge trench and backfill, or no cover rock berm
KP 24.4–KP 50	20–50	Pre-dredge trench and sand cover, or post lay trenching

NB: Beyond 50 m water depth some sections may require dredging or post lay trenching for stabilisation purposes. Seabed material would be sidecasted, parallel to the trunkline route.

Table 4-6 Estimated Trunkline Dredge Spoil Volumes

Dredge Location	Volume (m^3)
Offshore trunkline route (beyond DPA limits)	1 500 000
Inshore trunkline route (within DPA limits)	2 000 000
Trunkline crossing West Intercourse Island to mainland	N/A
Total	**3 500 000**

4.5.3.3 Trunkline Shore Crossing

The preferred method for the construction of the trunkline shore crossing (Option 1 and Option 2) is open-cut dredging. This will entail a 50 m wide construction corridor between the high water and low water marks, and will include the following activities (**Figure 4-7**):

- *Nearshore Trench Dredging:* A backhoe dredge will be used to excavate the trunkline trench in nearshore waters from a point seaward of Lowest Astronomical Tide (LAT). A short section at the offshore/onshore interface may require drilling and blasting by a marine blasting spread. Blasted rock is subsequently excavated by backhoe dredge. Land-based excavators will be used to excavate the trench between LAT to the onshore end of the nearshore trench. A temporary groyne comprising rock fill material may be required to enable land-based excavators to operate effectively around LAT. Any igneous rock present in the trench alignment will require pre-treatment by blasting. A land-based drilling rig will be used, allowing the rock to be drilled through the groyne.
- *Bedding Material:* Prior to execution of the shore pull a small volume of bedding material will be placed inside the trench in areas where blasting has been used. The bedding material will be gravel or crushed calcarenite and is placed in the trench to protect the pipeline coating system during the pull.
- *Trunkline Installation:* The trunkline will be pulled ashore from the lay barge using a dead man anchor and winch located in the working corridor above the high water mark. Some temporary foundations will be constructed prior to the shore-pull for the winch, spool and hydrotesting spread.
- *Backfilling:* Once the trunkline and the MEG pipeline are pulled ashore and tested, the open-cut trench will be backfilled with rock at the immediate shore crossing location for stabilisation and protection of the system in the near shore and tidal zone area. It is likely that the trunkline will then transition above ground onto pipe racks once sufficiently clear of the high water mark.

Figure 4-7 Offshore and Nearshore Trunkline Construction Corridors

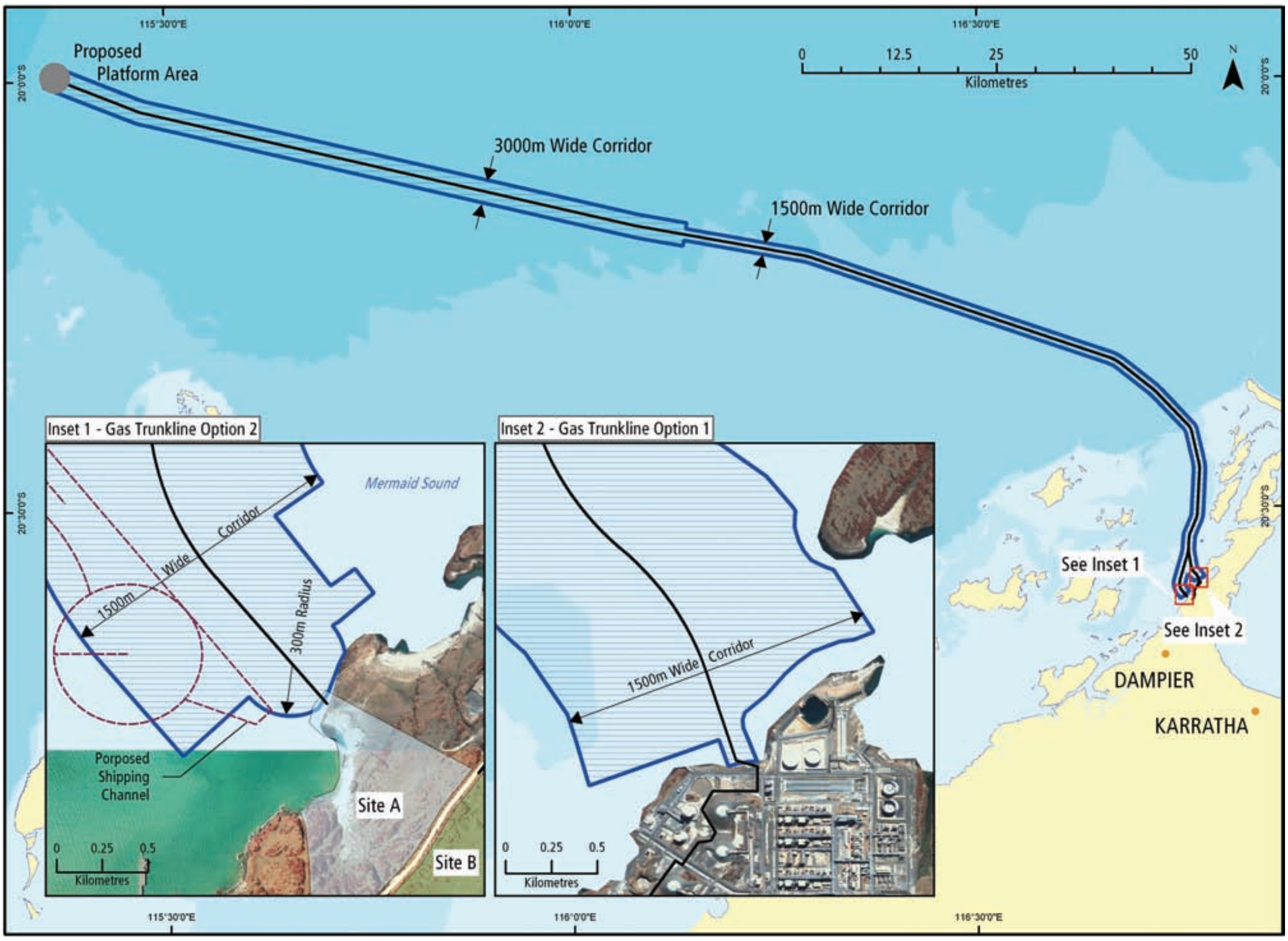


Figure 4-8 Trunkline Stabilisation by No Cover Rock Berm

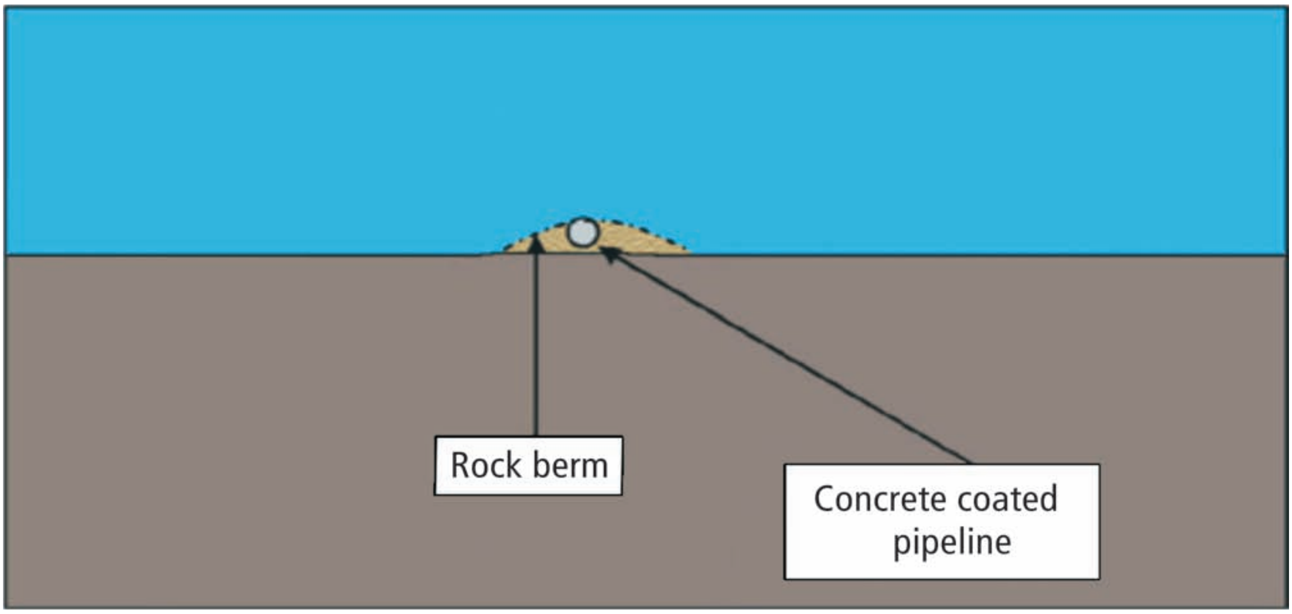
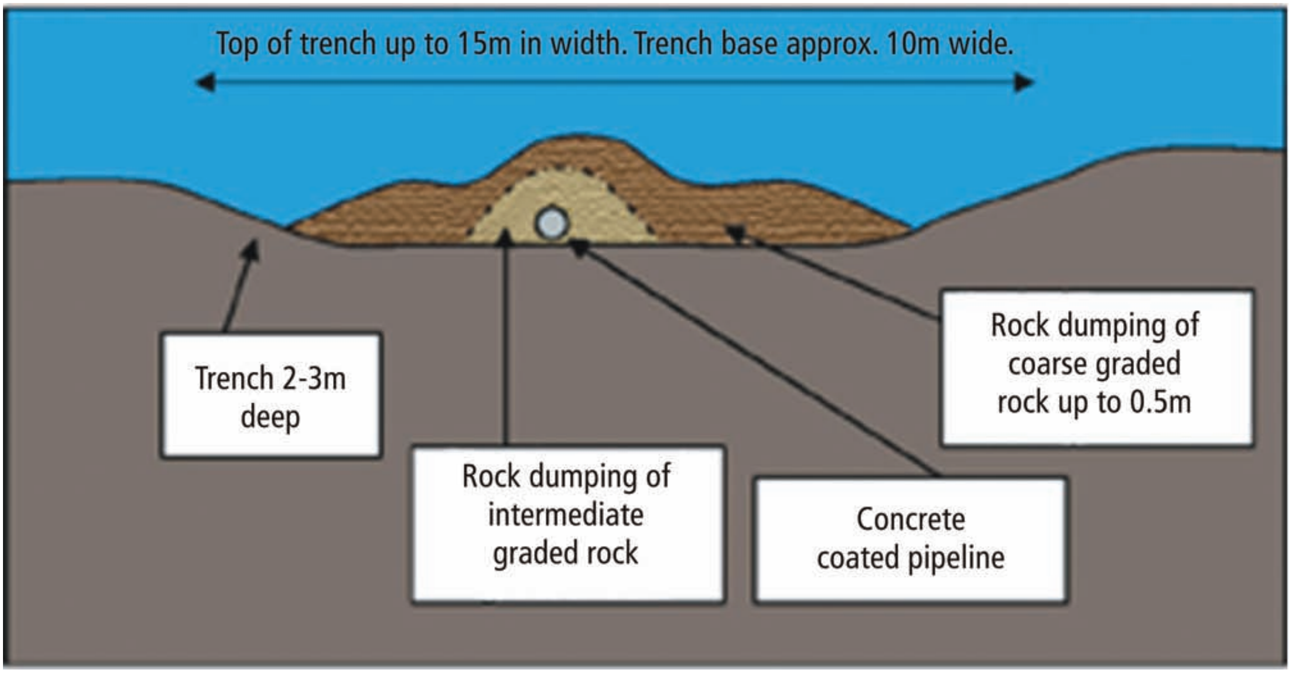


Figure 4-9 Trunkline Stabilisation by Rock Dumping



4.6 Nearshore Development

The Pluto LNG Development will require marine infrastructure to support both construction and operation activities on the Burrup Peninsula. The nearshore infrastructure will broadly comprise:

- a jetty comprising of a bridge and a causeway
- an offloading platform and berth capable of safely berthing the LNG and condensate tankers
- a dredged navigation channel consisting of a channel, turning basin and berth pocket
- treated waste water discharge pipeline with outfall located adjacent to mooring dolphins at end of jetty.

The preliminary layout of nearshore facilities is illustrated in **Figure 4-10**.

4.6.1 Material Offloading Facility

Construction of the gas processing plant will require the transportation of materials to the Burrup Peninsula. It is anticipated that the majority of material will be transported by barge. A Material Offloading Facility (MOF) will be required to safely offload materials, with sufficient capacity to be able to lift loads up to 3000 tonnes. The existing DPA MOF public wharf is the most likely MOF to be used for the Pluto LNG Development; however, other alternatives exist at the King Bay Supply Base and Mermaid Marine.

4.6.2 Jetty and Causeway

A stand-alone export jetty and causeway is required to transport personnel, product, services and material from the adjacent Site A to an offloading platform. The proposed jetty layout is shown in **Figure 4-11**.

A causeway, which will connect to the jetty, will be comprised of fill material overlain with rock armour. It is likely that the fill material will comprise rock and material excavated from site preparation activities associated with onshore facilities. The causeway will be approximately 50 m in length and will support product pipelines and an access road. The stand-alone export jetty and causeway option will be designed to withstand a 1-in-100 year return period cyclone conditions.

The construction of the jetty cannot commence until dredging of the turning basin and berth pocket are underway. A period of 12–15 months will be required for construction of the jetty. The main inshore activities will include piling using a pile hammer from a pile barge. Construction activities will include:

- preparation of an access road between the causeway and Site A
- installation of an earth causeway complete with large rock armour
- piled foundations for the jetty, the offloading platform and the dolphin berths
- installation of the jetty, offloading platform and dolphin berths
- installation of loading platform
- berth installation
- installation of equipment, piping and services.

4.6.3 Offloading Platform and Berth

An offloading platform and adjacent berth will be required to enable the export of LNG and condensate product from the storage and export tank facilities located at Site A. The offloading platform will be on the southern side of the jetty. The LNG and condensate facilities will consist of up to six offloading arms and associated equipment.

A single dedicated berth will be provided, sized to accommodate LNG tankers ranging from 165 000 m^3 to 210 000 m^3, and condensate export tankers up to 115 000 m^3. The berth will be made of a number of inter-connected dolphins that will also carry the necessary mooring equipment.

4.6.4 Navigation Channel

To allow safe access to the jetty location within Mermaid Sound, a navigation channel, turning circle and berth pocket will be developed. The navigation channel will be approximately 10 km in length and 250 to 275 m wide at the bottom of the channel. Based on preliminary investigations, the design configuration is outlined in **Table 4-7**.

Table 4-7 Navigation Channel Water Depth Requirements

Component	Water Depth (m)
Navigation Channel (approx 10 km)	Up to 13.5
Turning Basin	Up to 13.0
Berth Pocket	Up to 13.5

4.6.5 Dredging

Dredging will be required along the navigation channel route, to allow safe approach, berthing and departure of the LNG tankers and condensate tankers. Dredging will also be required along sections of the trunkline route for protection of the trunkline (**Section 4.5.3.3**).

This section describes a preliminary dredging programme. It is expected that the programme will undergo some modification following additional detailed studies, geotechnical surveys and selection of the dredging contractor.

It is expected that dredging of the navigation channel, turning basin and berthing pocket will produce between 10 and 12 Mm^3 of spoil, of which an estimated 75 to 85% will be marine sediments (medium to fine sands, silts and clays) and 15 to 25% will be limestone rock and conglomerate/igneous rock. In addition, it is expected that dredging of the nearshore trunkline trenches will produce approximately 1 to 2 Mm^3 of spoil from within the DPA limits of predominantly marine sediments. The total expected quantity of spoil from within DPA limits is therefore expected to be between 11 and 14 Mm^3.

The estimated material dredge volume will be confirmed following further engineering studies and confirmation of the size of LNG and condensate vessels that can be catered for by the Pluto LNG Development. Dredging is estimated to take up to 24 months to complete with a start date in Quarter 3, 2007 (**Figure 4-12**) assuming that there is no requirement for blasting, which may add another three to six months to the schedule.

A number of dredging vessels are likely to be required, operating on a 24 hour basis during construction of the navigation channel, berth pocket and turning circle, including:

- cutter suction dredge (**Figure 4-13**)
- trailer suction hopper dredges (**Figure 4-14**)
- mini jack up drill and blast barge vessel.

A typical approach would consist of using a medium sized (8000–11 000 m^3) trailer suction hopper dredge to remove the unconsolidated marine sediments from the seabed via suction pipes or 'drag arms' which are lowered from the hull of the vessel. The suction pipes are suspended from gantries and with the assistance of swell compensators, dredging can be maintained in a 2–3 m swell. The material is then pumped to hoppers where solids settle out and water is discharged at keel level. When the hoppers are full the vessels travel to the disposal area where the contents will be discharged via bottom opening doors to the seabed.

A cutter suction dredge will be used to cut harder material from the seabed as the channel depth progressively deepens. This material is likely to be deposited back into the same location from which it was cut and reclaimed from the seabed by the trailer suction hopper dredge at a later date, for subsequent disposal to spoil grounds or for possible re-use as trunkline backfill and cover.

For harder materials that cannot be dredged (such as dolerite rock and cap rock), limited drill and blasting activities may be required using drill rigs from a jack-up barge. It is likely that if blasting is required (which is not currently anticipated) the blasted material will be picked up either by a trailer suction hopper dredge, backhoe dredge or clamshell dredge and disposed of at one of the proposed disposal grounds.

Large jumbo-sized dredgers capable of holding greater than 20 000 m^3 would provide increased cost-effectiveness for transport of spoil to the spoil disposal grounds to the north of Mermaid Sound. However, because of the deeper draught requirements, it is not feasible to use such vessels for the dredging operations.

The durations and expected seasonal timing of each of the dredging activities are summarised in **Figure 4-12** and the key tasks listed in **Table 4-8**.

4.6.6 Dredge Spoil Disposal

The alternative spoil disposal methods considered and the process for selection of disposal sites is described in **Section 7.9.4**. The proposed dredge spoil disposal plan is presented in **Table 4-9** and is the result of a detailed review of dredge spoil disposal and management options.

Dredge spoil from construction of the trunkline in deeper waters (20–50 m) will be disposed of approximately 1-2 km adjacent to the trunkline easement, at deep water Site 5A (**Figure 4-15**). The bounding coordinates for each of the proposed dredge spoil disposal grounds are provided in **Table 4-10** and their location illustrated on **Figure 4-15**.

Table 4-8 Description of Key Dredge Tasks

Task	Description
i.	Survey of dredge area and mobilisation of dredge equipment to site
ii.	Trailer suction hopper dredge #1 cleans out turning basin and berthing pocket of overlying marine sediments. Sediment is disposed of at spoil ground A/B (area CDG as shown on **Figure 4-15**). When complete, trailer suction hopper dredge #1 moves onto dredging channel areas
iii.	Cutter suction dredge cuts underlying limestone and leaves in situ for trailer suction hopper dredge #2 to pick up
iv.	Trailer suction hopper dredge #2 cleans out cut limestone from turning basin and berthing pocket before moving onto channel. Spoil disposed of at spoil ground A/B (area CDHIEF - **Figure 4-15**), northern extension of A/B (area ABCD - **Figure 4-15**) and residual spoil disposed of at deep water site 2B
v.	Cutter suction dredge cuts areas of limestone along navigation channel
vi.	Trailer suction hopper dredge #1 arrives at navigation channel after cleaning out turning basin and commences working along channel removing overlying sediment. Spoil disposed of at deep water site 2B
vii.	Trailer suction hopper dredge #2 moves from picking up and disposing of cut limestone from turning basin and berthing pocket to navigation channel where it commences removing overlying marine sediment and cut limestone left by the cutter suction dredge. Spoil disposed of at deep water site 2B or as back fill for trunkline
viii.	If required, blasting of igneous rock
ix.	Trailer suction hopper dredge #1 picks up and disposes of rock spoil at spoil ground A/B (area CDHIEF - **Figure 4-15**) or northern extension of A/B (area ABCD - **Figure 4-15**)

Table 4-9 Dredge Spoil Disposal Locations

Spoil Source	Spoil Type	Spoil Ground A/B – Northern (Area CDG)	Spoil Ground A/B- West and East Margins (Area CDHIEF)	Northern Extension of Spoil Ground A/B (Area ABCD)	Deep water Site 2b	Trunkline Backfill and Cover	Deep water Site 5a
Turning Basin and Berth Pocket	Sediment	T					
	Coarse Material		T	T	T	?*	
Navigation Channel	Sediment				T		
	Coarse Material				T	?*	
Gas Trunkline (Option 1 or 2 within DPA limits)	All		T	T	T		
Gas Trunkline (Beyond DPA limits)	All						T
Approximate Volume within DPA limits (Mm^3)		2.0–3.0		1.5	8.0–10.0	1.0	

** subject to further analysis of likely spoil volumes and characteristics*

Figure 4-10 Preliminary Layout of Nearshore Marine Facilities

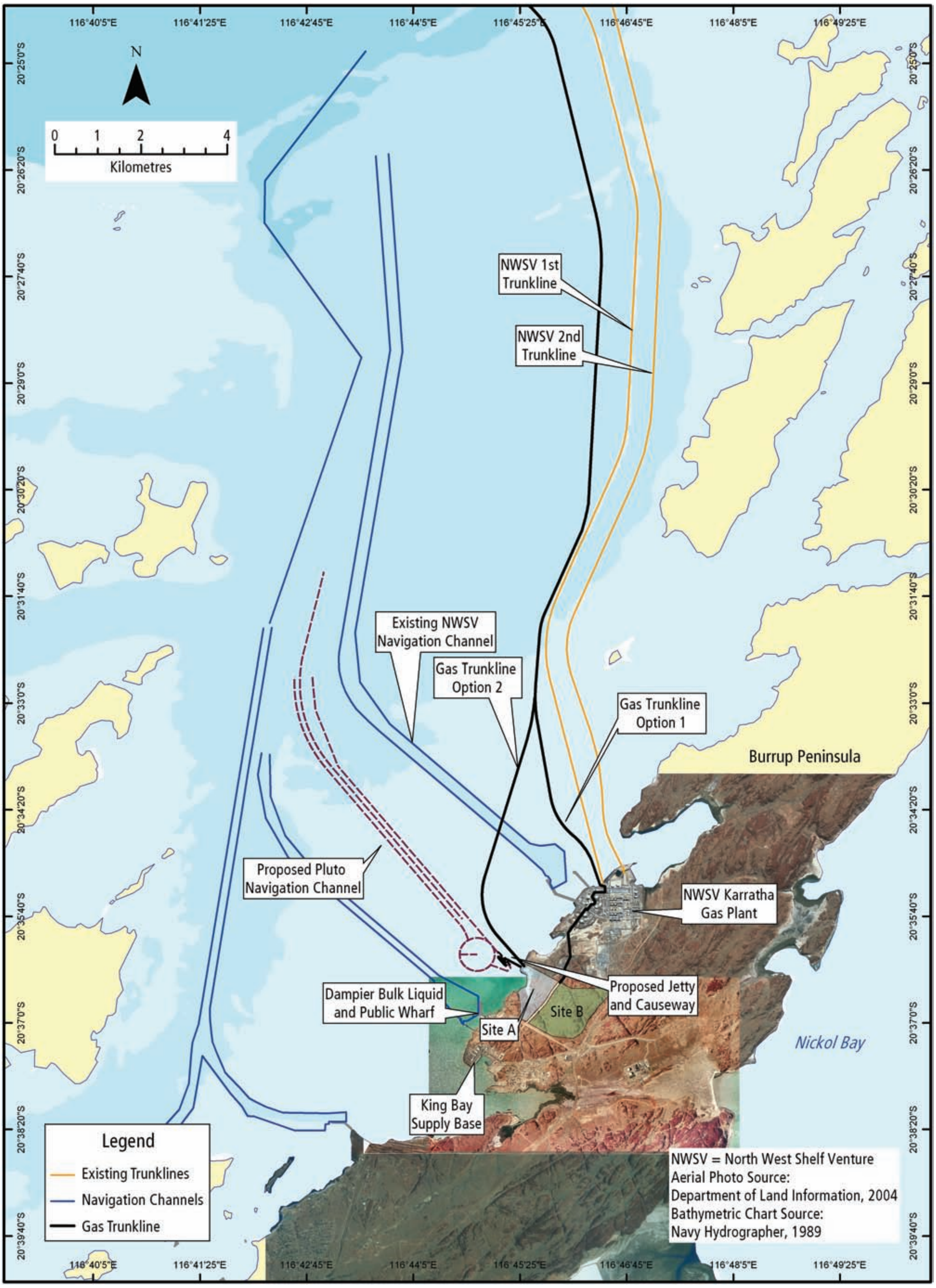


Figure 4-11 Proposed Jetty Layout

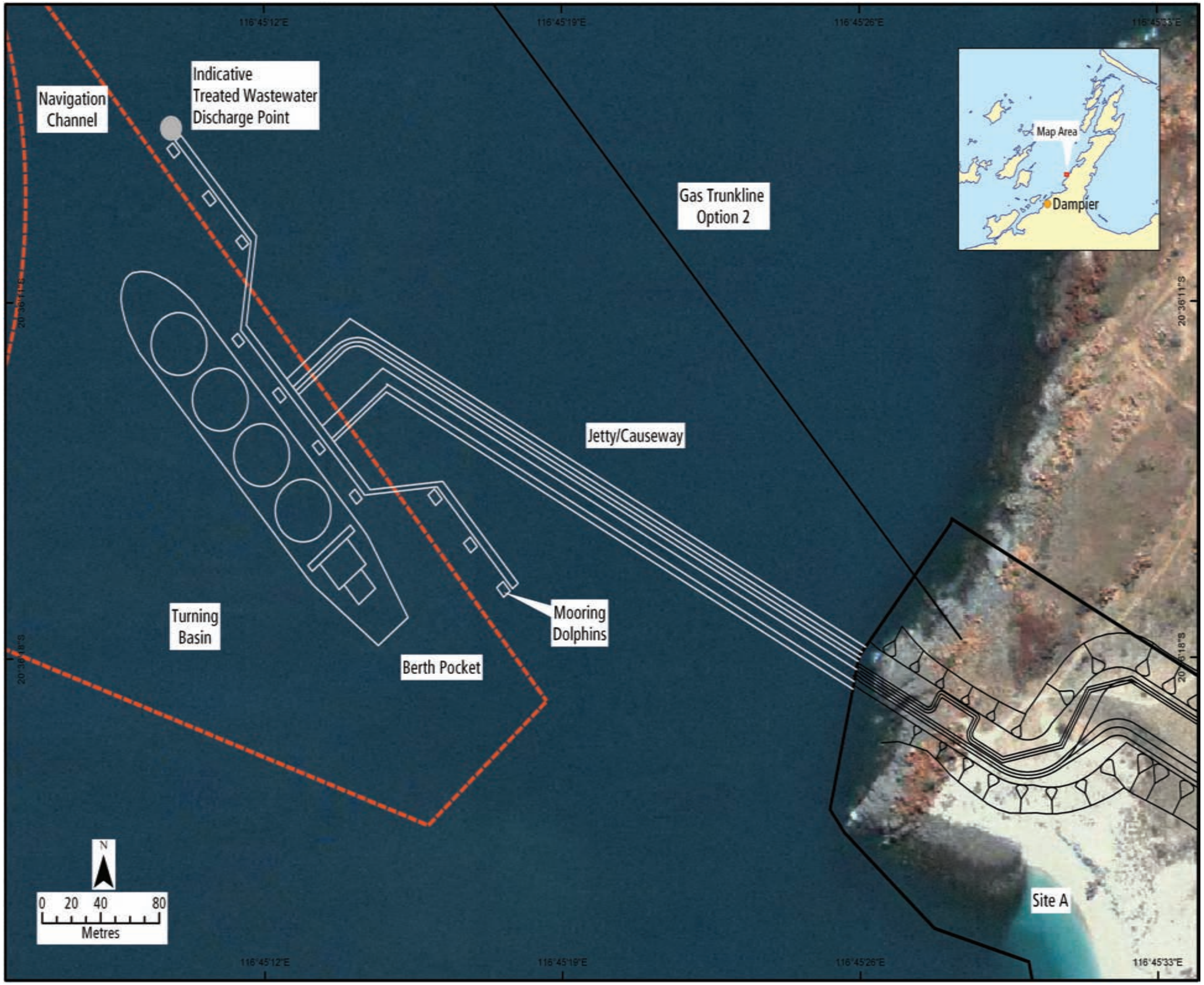


Figure 4-12 Provisional Dredging Schedule

Project Activities		2007								2008												2009												2010		
	Task	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Survey	i																																			
Turning Basin, Berthing Pocket																																				
Trailer Suction Hopper Dredge 1	ii																																			
Cutter Suction Dredge	iii																																			
Trailer Suction Hopper Dredge 2	iv																																			
Channel																																				
Cutter Suction Dredge	v																																			
Trailer Suction Hopper Dredge 1	vi																																			
Trailer Suction Hopper Dredge 2	vii																																			
Blasting (if required)																																				
Mini Jack up	viii																																			
Trailer Suction Hopper Dredge 1	ix																																			

Figure 4-13 Cutter Suction Dredge

Figure 4-14 Trailer Suction Hopper Dredge

Table 4-10 Co-ordinates of Proposed Spoil Disposal Grounds

Spoil Ground	Easting	Northing
Spoil Ground A/B and Northern Extension		
Point A	473 800	7 731 640
Point B	475 900	7 731 640
Point C	473 637	7 731 340
Point D	475 737	7 731 340
Point E	473 850	7 731 040
Point G	475 250	7 730 400
Point H	472 697	7 729 340
Point I	473 000	7 729 340
Point J	474 797	7 729 340
Deep Water Spoil Ground 2B		
NW corner	467 887	7 747 168
NE corner	469 365	7 747 171
SE corner	469 368	7 745 741
SW corner	467 890	7 745 739
Spoil Ground 5a		
NW corner	427 443	7 762 727
NE corner	427 725	7 763 677
SE corner	466 894	7 749 783
SW corner	465 809	7 749 395

Co-ordinate Datum: AGD84

4.7 Onshore Development

4.7.1 Onshore Gas Trunkline

A series of onshore pipelines will be required including a trunkline delivering gas from the Pluto gas field to the gas processing plant at Site B. The trunkline shore crossing will either be at the existing Karratha Gas Plant (gas trunkline Option 1) or at Site A, Holden Point (gas trunkline Option 2). Land tenure along each of the trunkline options is described in **Section 10.5**. A brief description is provided below and identified in **Figure 4-16**.

- *Gas Trunkline Option 1:* Gas trunkline Option 1 comprises a shore crossing just north of the existing NWSV Karratha Gas Plant. The trunkline will make landfall at a small beach which is submerged at high tide. From here it will transect through the Karratha Gas Plant, over disturbed land and quarries to the south of the Karratha Gas Plant and then follow the existing NWSV Haul Road until it reaches Site B. In total, the onshore section of gas trunkline Option 1 will be approximately 3 km in length.

- *Gas Trunkline Option 2:* This option involves a shore crossing at Holden Point, Site A. The trunkline will be laid under the existing NWSV Haul Road as it crosses from Site A to Site B and will be approximately 1.5 km in length.

4.7.1.1 Construction Activities

Should gas trunkline Option 1 be selected, the trunkline route will be a combination of above ground pipe racks through the NWSV Karratha Gas Plant, and either buried or on pipe racks from the Karratha Gas Plant to Site A. If buried, the onshore trunkline will be constructed using standard construction methodologies which will include the following activities:

- *Preparation of Construction Corridor:* A pre-construction survey will be undertaken following receipt of regulatory approvals, which will include marking the trunkline centreline using pegs, followed by the construction corridor boundary. Drainage will be installed where necessary. This will enable the construction contractor to temporarily lower the water table if necessary to keep the trench dry during trunkline installation.

- *Topsoil Stripping and Grading:* Vegetation will be removed to a minimum width that allows trench digging, storage of trench spoil material and access for construction machinery. The trunkline trench will be cleared of topsoil and graded using graders and backhoes. Topsoil will be separated from other stockpiled soil and set to one side of the trunkline trench. Physical disturbance will be restricted to the condstruction corridor.

- *Drill and Blasting:* Drill and blast techniques may be required.

- *Trenching:* Bucket wheel trenchers and hydraulic excavators will be used to undertake the trenching. The trunkline trench will be dug to approximately 2 m depth, which will give the trunkline approximately 900 mm of soil cover when backfilled. Depending on the nature of the ground, it may be necessary to drill and blast some sections. This will be confirmed following completion of geotechnical investigations.

- *Stringing and Bending:* Trunklines will be assembled (including stringing, welding and field coating) along the construction corridor. Trunkline joints will be collected from designated laydown areas and transported to the construction site and placed on skids to prevent damage to the pipeline coating.

- *Trunkline Lowering:* Side boom tractors fitted with lifting cradles will be used to lower the trunkline into the trench. This operation will be carried out immediately following the opening of the trench.

- *Hydrotesting:* Once laid, the trunkline will be hydrotested to ensure integrity (refer to **Section 4.8.2.1**).

- *Backfilling:* Once tested, the trunkline trench will be backfilled and compacted.

- *Road Crossings:* The crossings are likely to be accomplished either by thrust boring, micro-tunnelling, culverts or horizontal directional drilling.

- *Rehabilitation and Reinstatement:* The gas trunkline Option 1 will transect through the NWSV Karratha Gas Plant, previously disturbed land which will be reinstated to the same condition as it was prior to construction. No permanent fencing will be provided along the trunkline route.

All trunkline construction activity will be confined to a 50 m construction corridor. The construction of the onshore gas trunkline is anticipated to take one month to complete.

Should gas trunkline Option 2 be selected the trunkline will be routed from the shore crossing north of the jetty to the Site B pig receiver upstream of the slug catcher (**Figure 4-17**). The trunkline corridor will lie parallel to the Site A access roadway and the pipe supports will most likely be constructed on the side of an earthen embankment made from rock fill sourced from the site preparation works within Site A (Woodside 2006a). Disturbance during construction of the pipe racks and installation of the trunkline will be above ground; therefore rehabilitation will not be required.

Road crossings within Site A, and from Site A to Site B, are likely to be accomplished using an open cut method. An open cut road crossing will involve digging a channel through the existing road (or prior to installation of a road where a new road within the site is to be built), installing a concrete culvert and then reinstating the road over the top of the culvert. A temporary small bypass road next to the works will be built during these operations to enable the road to be utilised during construction. The trunkline will then be constructed and pulled through the culvert. It is likely that the open cut method will be used for road crossings, however if it is not deemed suitable for geotechnical, operational or other reasons, an alternative method such as thrust boring, micro-tunnelling or horizontal directional drilling will be used. Once laid, the trunkline will be hydrotested to confirm the integrity of the pipeline (refer to **Section 4.8.2.1**).

Other smaller onshore above ground pipelines will be required to transport LNG, condensate and boil off gas water and waste water between the gas processing plant at Site B and the storage and export facilities at Site A. It is anticipated that these pipelines will be carried within a 10 m wide corridor.

4.7.2 Gas Processing Plant

4.7.2.1 Overview

The gas processing plant will be located at Site B (approximately 130 ha in size), an area gazetted by the Western Australian Department of Industry and Resources (DoIR) for industrial use. On arrival at the gas processing plant, the gas will be initially cleaned, the water removed and subsequently processed into LNG and condensate, stored and exported. Once processed, LNG and condensate will be piped from Site B to Site A, which is approximately 61 ha in size.

The gas processing plant will be designed to accommodate flexibility in the supply of feed gas from offshore allowing the facilities to potentially utilise future gas from other fields. The gas processing plant will have a 30 year design life and a maximum processing capacity of up to 12 Mtpa. The plant layout proposed for Site B is illustrated in **Figure 4-17**. The proposed layout of the tank storage and export facilities is presented in **Figure 4-18**.

4.7.2.2 Construction Activities

Construction of the gas processing plant is likely to be carried out using modular building techniques involving the transportation of pre-assembled units to site for assembly, as well as in-situ construction of facilities. This method is anticipated to require approximately 36 months, which also includes offsite construction time for some of the gas processing plant components.

The construction of the plant is anticipated to require a workforce of between 1500 and 2700 personnel during peak construction periods. This workforce is likely to be accommodated in the townships of Karratha and Dampier and transported to the site by bus each day. Working hours are likely to be limited to 7 am–6 pm for the majority of the construction period, although there may be a requirement for 24 hour operations. This will be determined by the construction contractor.

Construction of the onshore gas processing plant to the point of commissioning will involve a series of activities including:

- earthworks – clearing and levelling the construction site, including cut and fill activities and rock supply
- blasting of base rock
- creation of temporary laydown areas and access roads
- piling – ensuring suitable ground conditions for foundations
- supply and installation of concrete batch plant
- laying site drainage and internal roads
- transportation of materials to site including use of port facilities and external road transport infrastructure
- installation of processing plant
- construction of buildings and enclosures (for example, administration building, warehouses, workshops and control rooms)
- construction and installation of utilities and services (for example, power generation, tool and instrument air, fire water)
- landscaping and reinstatement.

Figure 4-15 Proposed Dredge Spoil Disposal Grounds

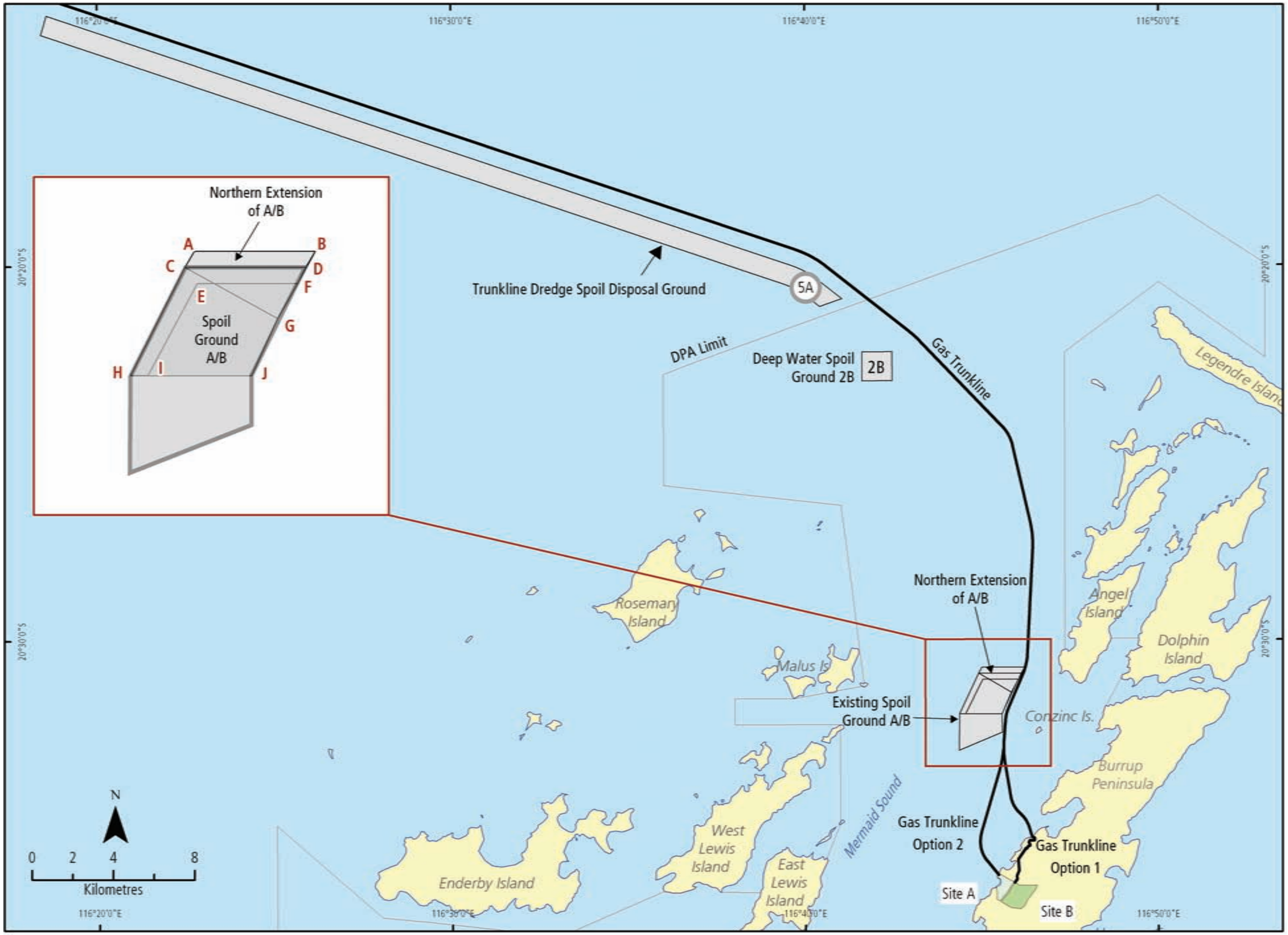


Figure 4-16 Onshore Trunkline Options 1 and 2

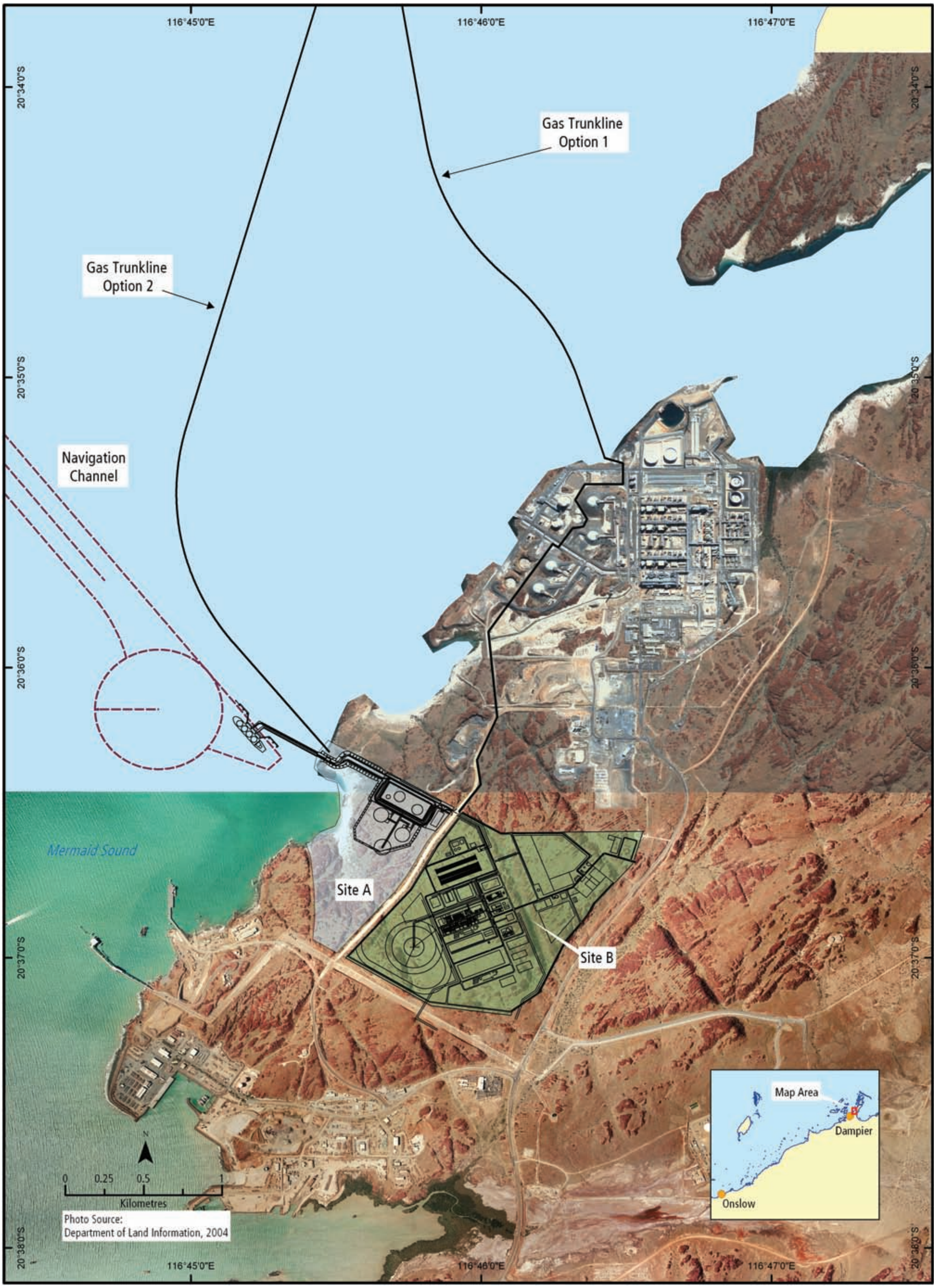


Figure 4-17 Site B Gas Processing Plant Layout

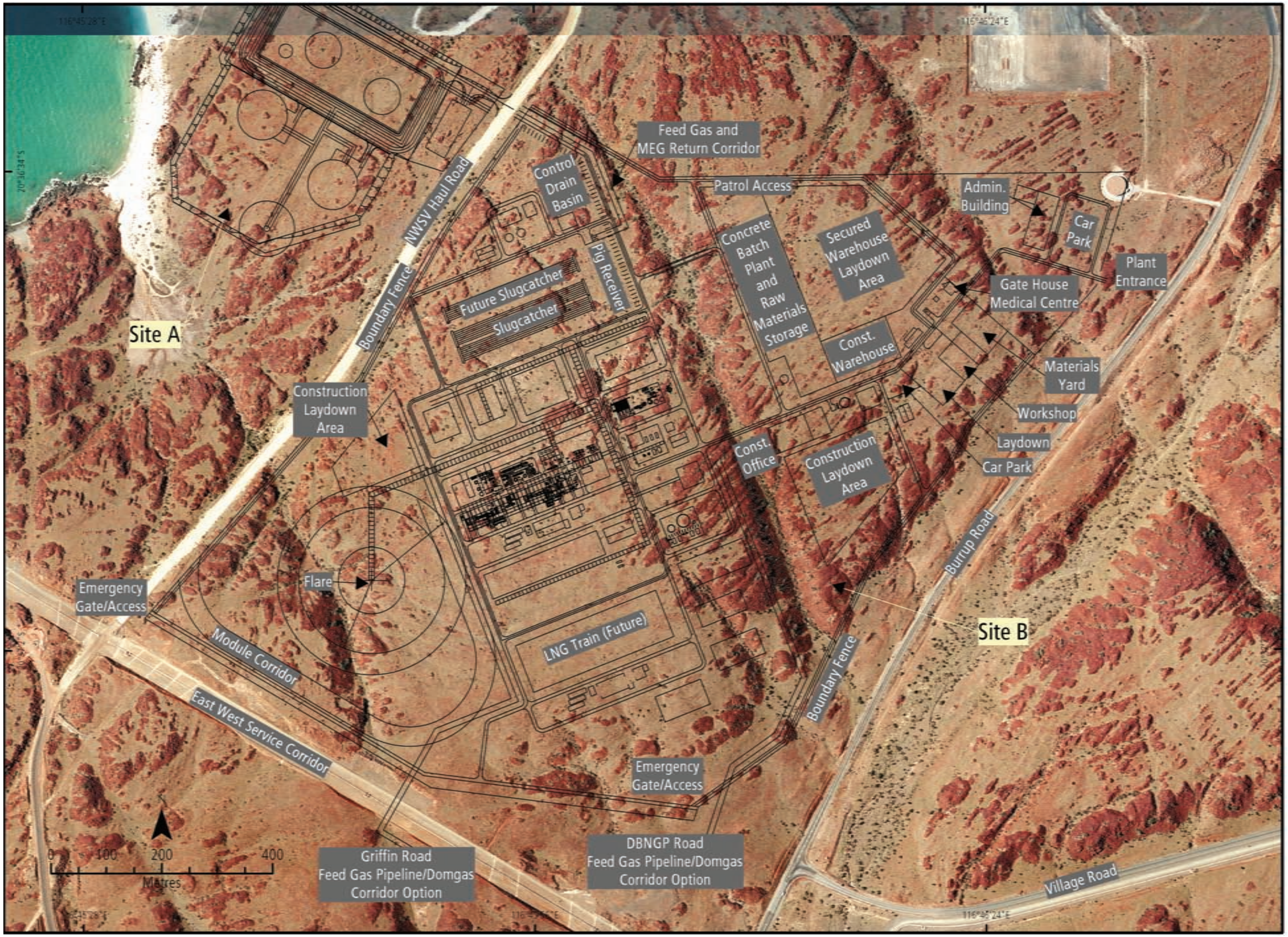


Figure 4-18 Site A Gas Storage and Export Facilities Layout

Earthworks: Preparation of the gas processing plant site will require significant earthworks and excavation of mainly rock material to prepare an appropriate ground condition for construction. The amount of earthworks required will depend on geotechnical investigations, however it is anticipated that the plant will be located on a benched site. Preliminary platform levels have been identified and will be confirmed during Front End Engineering and Design and include:

• processing trains	RL 58 m and 60 m AHD
• MEG regeneration facilities	RL 56 m AHD
• pigging and slugcatcher facilities	RL 54 m AHD
• workshop and laydown areas	RL 78 m AHD
• administration area	RL 72 m AHD.

These levels reflect the general topography of Site B and have been selected to minimise requirements for rock, whilst maintaining suitable foundations to support the gas processing plant. Interpretation of existing geological and geotechnical data for Site B indicates that drilling and blasting will be required across much of the site to achieve proposed platform levels. Material cut from the site will be relocated to other areas on Site B where it will be used as fill material. A rock crusher may be used to create suitably sized material for use as backfill material, however, additional fill material may need to be imported. Conventional earthmoving equipment is expected to be suitable for excavation of some of the materials, although hydraulic rock breakers and blast rigs will be required where bedrock is encountered.

The requirements for construction machinery are likely to include drill rigs, excavators, bulldozers, pick ups / light duty vehicles, water trucks (10 000 l), cranes, minibuses, transit mixers, forklifts, truck mounted concrete pumps, compressors, power generators, compactors, tipper trucks, trailers, fuel / lube trucks (4000 tonnes), flatbed trucks, excavators and pumps.

Piling: The requirements for piling will be determined following geotechnical investigations.

Concrete Batch Plant and Warehouse: Land within Site B will be used during construction for a concrete batching plant, laydown area, warehouse and administrative offices (**Figure 4-17**). The batching plant will be required to produce several thousand cubic metres of concrete for footings and plant structures. The laydown area and warehouses will be used for storage of equipment and materials.

Site Drainage and Internal Roads: Once the site has been levelled to the required elevations, internal roads and site drainage will be installed. Internal roads will include a combination of bitumen surfaces for main roads and crushed rock for minor roads. The gas processing plant, located in the centre of Site B will be connected to administration buildings and the site entrance and main car park located in the north east of the site by two bridges. The two bridges will traverse a gully, one of three significant drainage features which transect the site.

Flows of up to a 1–in–10 year storm event will be conveyed within a closed pipe system or open channel drainage system. The treatment of storm water discharge is discussed in **Section 4.7.6**. Uncontaminated stormwater will be diverted into existing drainage channels.

Transportation of Materials to Site: Existing transport infrastructure on the Burrup Peninsula will be used as far as practicable to minimise the disturbance footprint. It is anticipated that the majority of construction materials will be imported to site by barge to the DPA public wharf (**Section 4.6.1**). Materials will then be transported to Site A and Site B from an existing MOF via the MOF Road and the NWSV Haul Road (**Figure 4-3**) on large flat loader vehicles capable of transporting materials between 1500–3000 tonnes in weight. No road widening requirements are anticipated to accommodate these vehicles.

Site Reinstatement: Following the completion of all construction activities, disturbed areas that do not need to remain cleared will be rehabilitated.

Quarries: In the event that sufficient quantities of rock cannot be supplied from within Site A and Site B Woodside will assess the use of alternative existing commercial quarry sites.

During construction of the tank storage and export facilities at Site A, it is anticipated that a perlite furnace will be required onsite to manufacture insulation for the tanks.

4.7.3 Gas Processing

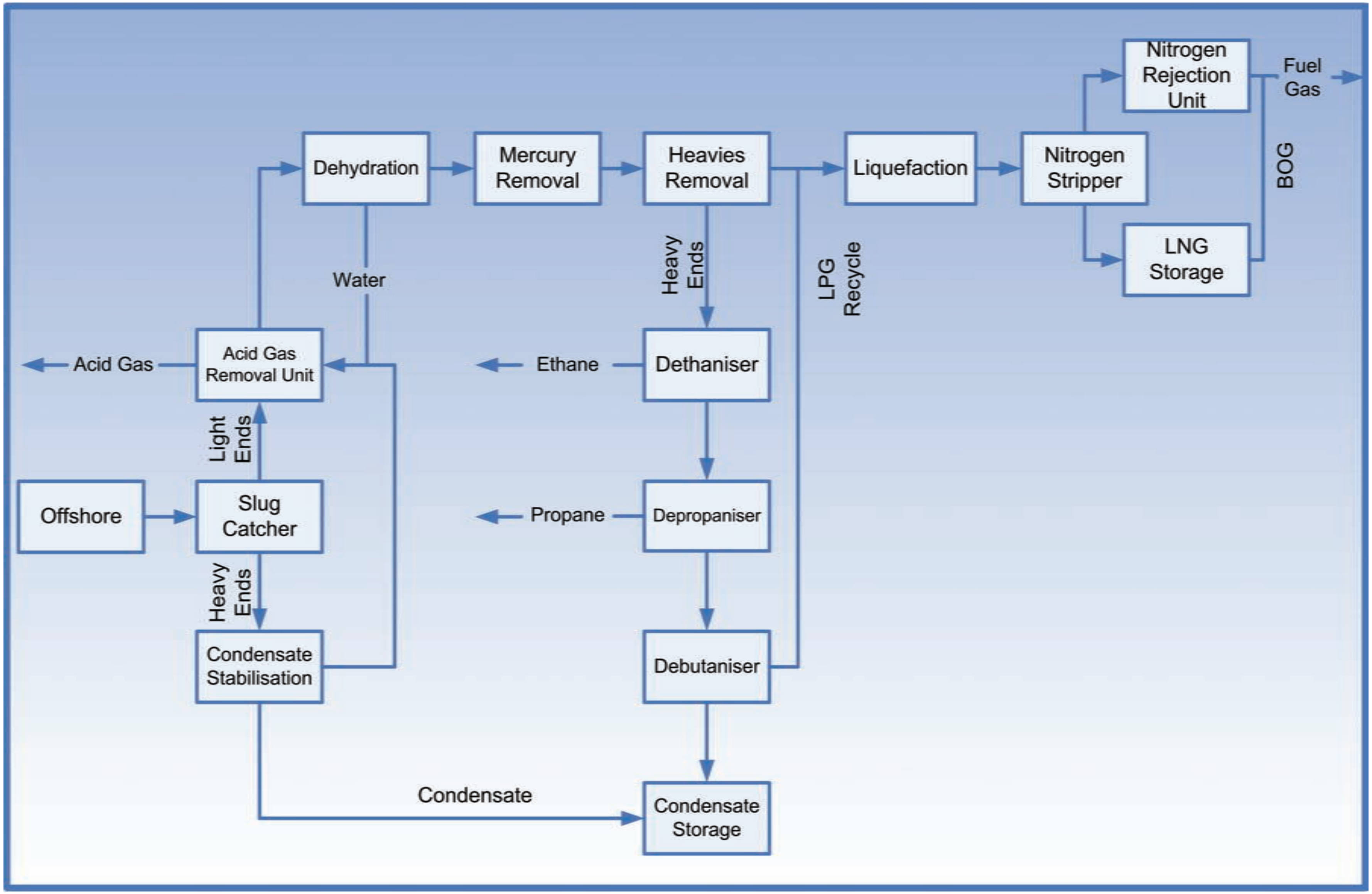
The following sections provide a description of the main components of the gas processing plant.

Liquefied natural gas will be produced through the cooling of natural gas below its condensing temperature of -161°C. In a liquid state, the gas volume is one six hundredth of its volume in gaseous form and therefore can be stored and transported in smaller tanks and carriers. The production of LNG and condensate at Site B will involve the following process phases.

- gas receivable and inlet separation
- acid gas removal
- gas dehydration
- mercury removal
- liquefaction
- end flash and nitrogen removal
- fractionation/ heavies removal
- refrigerant storage
- condensate stabilisation and export.

A process flow diagram for LNG production is shown in **Figure 4-19**.

Figure 4-19 Pluto LNG Development Process Flow Diagram



Gas Receiver and Inlet Separation: Fluids from the trunkline arrive at an onshore slugcatcher (inlet scrubber) located at Site B. The slugcatcher's function is to separate condensate from water and gas, and to act as a buffer between the trunkline and the downstream processing plant. The slugcatcher will ensure that a stable gas flow is provided to the Acid Gas Removal Unit (AGRU). The condensate stream will be routed to the condensate stabilisation unit, where the liquids will be stabilised to the required Reid Vapour Pressure (RVP) Specification and cooled. The condensate stabilisation unit compresses the stabilised overhead gas from the condensate stream for return to the process. The condensate is then combined with fractionation bottoms and routed to the condensate storage and export facilities at Site A. Water separated from gas and condensate will be routed to the MEG regeneration unit to regenerate the MEG. The MEG will be returned offshore and the produced water will be directed to the wastewater treatment plant for treatment and disposal.

Acid Gas Removal: The feed gas from the slugcatcher is routed to the AGRU / amine treatment unit where CO_2 and sulphur components present in the gas are removed. The CO_2 is removed to prevent 'freezing out' within the cryogenic equipment, by means of activated Methyl Diethanolamine (aMDEA), a tertiary amine. This is a non-corrosive aqueous based solution. The CO_2 is removed by active absorption (counter current circulation of feed gas with aMDEA solution). Some low levels of hydrocarbons including benzene, toluene, ethylbenzene and xylene (BTEX) are co-absorbed during the acid gas removal stage. Typically the use of aMDEA as opposed to the traditional acid gas removal solvents will reduce the co-absorption of hydrocarbons by greater than 80%. The vented CO_2 stream, consisting mainly of CO_2 and water, will be passed through a thermal oxidiser to ensure that any remaining hydrocarbons are converted to CO_2. The thermal oxidiser will also remove approximately 98% of BTEX from the feed gas.

Gas Dehydration: Treated gas from the AGRU is routed to a dehydration unit, which will dehydrate (remove water from) the feed gas stream to prevent water freezing out in the cryogenic equipment. The gas will be chilled to a temperature slightly above the hydrate point in order to remove as much water as possible. The chilled gas is then dried in a molecular sieve system to remove the final traces of water and to prevent any downstream formation of ice. After cooling and water removal, the regeneration gas will be compressed back to the main feed immediately downstream of the amine contactor. The dehydration system will be configured with 3 x 50% mole sieve vessels, which will allow two vessels to run in parallel absorption mode, whilst the other is in regeneration mode.

Mercury Removal: Possible trace quantities of mercury will be removed from the gas stream to prevent corrosion of the heat exchanger tubes. A mercury removal unit is likely to comprise a single bed of sulphur impregnated activated carbon. As soon as the gas passes over the bed, the sulphur reacts with the mercury in the gas and the mercury becomes embedded into the carbon granules. The carbon beds containing mercury will require periodic disposal and their disposal and management is described in **Section 5.3.6**.

Fractionation / Heavies Removal: Before the gas can be liquefied, heavy hydrocarbons which would otherwise freeze out in LNG need to be removed. For this process the liquefaction unit receives heavy hydrocarbons from the scrub column bottoms and treats them to produce refrigerant for make-up, a Liquefied Petroleum Gas (LPG) stream for re-injection into the main process and a C5+ ('pentane plus') stream which forms part of the condensate product.

The fractionation unit is configured as a single train, comprising a de-ethaniser, de-propaniser and debutaniser. The following refrigerant streams will be produced:

- ethane vapour for continuous make-up to the mixed refrigerant loop
- ethane liquid for storage

  propane liquid for storage.

The debutaniser bottoms stream is combined with the stabiliser bottoms to form the product condensate stream. The composition of the debutaniser bottoms must be such that the condensate product meets the Reid Vapour Pressure (RVP) specification.

Liquefaction: This process is the main component of each LNG train and essentially chills the natural gas to a temperature at which LNG is produced using a series of cryogenic heat exchangers. The liquefaction process includes a scrub column to remove heavy hydrocarbons to ensure that the product LNG complies with specifications and prevents freezing in the main cryogenic heat exchanger. The heavy hydrocarbon stream is sent to the fractionation system for further treatment.

The liquefied gas stream leaving the liquefaction system passes to the end flash system for further treatment.

End Flash Nitrogen Removal: The end flash system ensures that the product LNG stream leaving the storage and loading facilities (Site A) meets the Asia Pacific and US West Coast LNG product specification (for maximum nitrogen content). Rundown pumps are provided for transfer of LNG to the storage tanks. The end flash overhead stream passes through a nitrogen removal unit which produces a fuel gas stream and a reject nitrogen stream. Fuel gas exiting the liquefaction system will be at a pressure sufficient to meet the requirements of the highest fuel gas pressure user. The nitrogen reject stream will be vented to atmosphere (**Section 5.1.1.4**).

The LNG will then be piped to the storage and export facilities at Site A.

Refrigerant Storage: The propane and mixed refrigerants will be stored in liquid form to ensure sufficient make-up for the refrigeration loops is always available. Storage will be in spherical tanks. The refrigerants will be extracted directly from the feed gas.

4.7.4 Storage and Export Facilities

Gas storage and export facilities will be located at Site A and will comprise the following:

- two LNG tanks – each with a storage volume of up to 160 000 m^3 (approx. 75–100 m diameter)
- two or three condensate tanks with a total capacity of up to 130 000 m^3
- designated area for laydown and future storage
- substation
- field auxiliary room
- gatehouse and parking
- an LNG jetty security house and boom gate
- a jetty access road
- a pipe rack corridor for incoming and outgoing pipelines and services (including the feed gas trunkline for gas trunkline Option 2
- a flare system
- a boil off gas system (consisting of compressor, motor and power supply)
- drainage and effluent disposal facilities.

Sub-cooled LNG will be piped from the processing plant at Site B to the LNG cryogenic tanks located at Site A via two cold insulated pipelines. Back pressure will be provided on each tank to ensure that the pipeline remains liquid filled. The LNG tanks will have a full containment system, providing enhanced integrity for LNG storage. A circulation system will be provided to ensure that the LNG loading lines remain cold during holding mode operation. Condensate will be piped to the condensate storage tanks via a single un-insulated pipeline. The condensate tanks will be designed as external floating roof storage tanks, with double emission seals equipped with earthen bunds (with an impermeable layer such as plastic or concrete) for secondary containment. The LNG and condensate storage tanks will be constructed and bunded as per regulatory requirements.

The LNG and condensate storage tanks will take approximately 36 months to construct, test and commission.

The earthworks are likely to require a significant amount of drilling and blasting techniques in rocky areas. These activities, in addition to those at Site B, will be strictly controlled in accordance with regulatory requirements. Site preparation activities at Site A are covered under a separate PER entitled 'Development of Industrial Land on the Burrup Peninsula for Future Gas Development' (Woodside 2006a). Site preparation activities for Site A are therefore not included within the scope of this Draft PER.

4.7.5 Ancillary Systems and Facilities

Fuel Gas System: The onshore facilities will be run primarily with fuel gas rather than diesel. The required fuel gas pressure levels will be designed to accommodate all gas turbine users. Feed gas will be used as a secondary source of fuel gas and boil-off gas may also be used as fuel gas. Start-up and back-up fuel gas will be sourced from the Dampier to Bunbury Natural Gas Pipeline.

Main Power Generation: The power generation system will be located at the gas processing plant at Site B and will include the following key components:

- compressors, turbines and generators
- inlet air system with self cleaning filters and silencing systems
- exhaust system including ductwork, silencer and stack
- turbine lube oil system
- auxiliary cooling system
- dry low oxides of nitrogen (NOx) or dry low emission combustion system.

Waste Heat Recovery Units: Waste Heat Recovery Units will be provided to recover heat from gas turbines at the gas processing site (Site B). The units will provide process heat in the form of hot demineralised water to various components of the gas processing plant. The hot water will circulate through the gas processing plant to components that require heat, such as the aMDEA regenerator re-boiler(s), a scrub column re-boiler, a stabiliser re-boiler and to other users as required. Under normal operations, very little hot demineralised water will be discharged; instead it will continually be circulated through the gas processing plant.

Boil-Off Gas System: During normal operation, natural gas will be present within various pipelines including the rundown pipeline, the LNG storage tanks and in the offloading pipeline. The produced gas is handled by the boil off gas system. The configuration of the boil off gas recovery system will consist of a header leading to two parallel centrifugal boil off gas compressors of identical capacities. Normal operation will be a single compressor for holding mode with an additional boil off gas compressor used for ship loading mode. The header will be connected to the vapour spaces of the LNG tanks and the vapour return line from the LNG jetty. The capacity of the boil off gas compressors will be sufficient to handle the boil-off generation rates arising from the holding mode and the loading mode, whilst at the same time, not flaring.

During tanker loading operations the quantity of boil off gas produced increases significantly. During loading, additional gas is generated from:

- export pumps
- the pressure differential between the LNG tanks and the LNG tanker vessel tanks
- heat loss through the LNG loading lines.

Removed boil off gas will be directed back to the processing facilities at Site B or may occasionally be flared at Site A.

Flare and Relief Systems: The Pluto LNG Development will minimise flaring by optimising the process design and effective maintenance of relief valves and pressure control valves, however, the onshore facilities will have two flare systems:

- Storage and loading flare system at Site A: Designed to safely collect and dispose of all releases due to depressurising, relief, maintenance and commissioning activities for the storage and loading facilities. In determining the final location of the flare, consideration will be given to a range of factors including heat radiation levels that could adversely affect hazardous materials, storage vessels (for example, fuel), communications equipment and exposed mechanical equipment.
- Pressure relief and liquid disposal flare system at Site B: Designed to safely collect and dispose of hydrocarbon containing streams that are released during start-up, shutdown, plant upsets and emergency conditions. The system will include a wet gas flare (wet flare), LNG flare and a common spare flare. The wet flare will be designed for wet vapour and warm blowdown and will include a knock-out drum to separate any liquids from the gas prior to it being routed to the LNG flare which will have permanently lit pilots and an ignition monitoring system. The LNG flare will be designed for dry vapour and cold blowdown and will also include a knock-out drum. Separate LNG vapour and LNG liquid disposal headers will be routed to the LNG flare knock-out drum. A common spare flare will be designed so that it is interchangeable between the LNG and wet flare systems whilst the plant is operational.

The flaring regime at Site A will include a continuous small pilot light at Site A and occasional flaring under certain circumstances including the flaring of boil-off gas to maintain low pressure in the storage tanks. Similarly, occasional flaring of gases from the LNG and condensate tanks may be required prior to ship loading. At Site B, flaring will occur continuously during the commissioning period for up to approximately six months as the system will at many times be too warm to produce LNG product. During operations, flaring will be intermittent and will occur during maintenance, shutdown and during upset conditions.

Regeneration of MEG: The MEG that has been transported in the trunkline from the offshore platform to the onshore gas processing plant will contain water and salts which will need to be removed to regenerate the MEG. The recovery process will involve the following steps:

- *Pre-Treatment* – The MEG solution will be separated from the wellstream fluids, the pipeline corrosion products and low soluble formation salts.
- *Storage* – MEG storage tanks will be provided and sized to contain storage for up to 10 days. Storage will be provided both upstream and downstream of the MEG re-concentration system, thereby enabling continued production in the event of a shutdown to this system. It will also provide a buffer, should one of the MEG re-concentration trains be out of operation during cleaning or maintenance.
- *MEG Re-Concentration* – The MEG re-concentration system re-generates the feed MEG from a concentration of around 30 to 45% (by weight) MEG to a lean product of 90% (by weight) MEG. This occurs when MEG is boiled/distilled at close to atmospheric conditions to remove incoming condensed and formation water that is dissolved in the feed MEG.
- *MEG Reclamation* – During this phase, highly soluble salts are crystallised and removed from the lean MEG which is in-turn routed to a flash separator. Removed salts will be re-dissolved into the water and removed during the re-concentration process. A small volume of insoluble salts will be removed as a solid waste stream.

Produced Water: Produced water (formation water and condensed water) will be separated from the MEG in the MEG regeneration unit at Site B. The volume of formation water received is likely to be up to a maximum of 160 m^3/day. The volume of condensed water is a function of the volume of gas transferred which is expected to remain at a maximum of up to 640 m^3/day. The formation water, condensed water and salt will be removed from the MEG then routed to treatment facilities located at Site B where it will be treated to levels sufficient to avoid potential for significant environmental impact before being discharged to Mermaid Sound. This discharge point will be located at the seabed near the end of the mooring dolphins of the export jetty (**Figure 4-11**).

After construction and commissioning of the second platform, most of the formation water and a portion of the condensed water within the wellstream fluids will be discharged to sea at the offshore platform location with a residual amount transported to the onshore plant where it will be treated prior to disposal. The treatment and disposal of the formation water and condensed water is discussed in **Section 5.2.15**. Consideration of alternatives to marine disposal of treated waste water generated during operations is discussed in **Section 3.6**.

Drinking and Service Water: The supply of drinking and service water will depend on the requirements of the processing, storage and export facilities, which have yet to be determined. A small stream of potable water (approximately 50 m^3/day) will be demineralised for use in the waste heat recovery processes.

Both the gas processing plant (Site B) and storage and export facilities (Site A) will be located in close proximity to existing mains water supplies. The supply source for this potable water is Harding Dam/Millstream. The combined drinking and service water requirements is expected to be less than 200 000 m^3/yr and it is expected that all requirements will be met by the Water Corporation supply, most likely from the Harding Dam/Millstream source. Consideration is being given to treating and re-using waste water generated by the facilities to offset part or all of the service water requirements of the gas processing plant and storage and export facilities. This is discussed in **Section 3.6**.

The gas processing plant will be equipped with a potable water system and will include a storage tank based on 48 hours normal use and drinking pumps, each electrically driven. A service water system will also be provided, and will be similar to the potable water system, with a tank and pumps. This service system will supply the demineralised water plant, process wash-down and general utility requirements and the service water tank will provide back-up fire water to the storage and export facilities at Site A.

Freshwater Cooling System: The major cooling system for the gas processing plant will be air finned coolers. In addition, a relatively small amount of cooling will be provided by a fresh water system supplying cooling water for motors and lube/seal oil skids within the LNG train(s). The refrigeration and end flash gas compressors will be the major consumers of cooling water. A closed loop cooling system may be provided, using demineralised water with corrosion inhibitors and biocides. As an alternative, the installation of integrated cooling loops for each user may be considered.

Fire Protection System: Fire water systems will be provided at both the gas processing plant and at the storage and export facilities. The fire water system at the gas processing plant will include a water storage tank and pumps, each rated for 100% of the total firewater requirements. A service water tank will act as a back-up water supply.

Fire fighting facilities at Site A will be similar to those provided at the gas processing plant and will service all hydrocarbon storage tanks and the loading jetty. It is anticipated that two fire water tanks will be provided, each sized to provide a six hour water supply for the worst-case fire scenario. As an alternative to a second storage tank, seawater may be pumped via the proposed jetty (refer to **Section 4.6.2**).

4.7.6 Drainage and Sewage Systems

Drainage facilities will be provided within Site A and Site B for stormwater and wastewater. The drainage systems will collect and convey drainage streams to an appropriate disposal location. This will be done in such a way to protect personnel and equipment, and to avoid environmental pollution. Drainage and sewage treatment will consist of the following facilities:

- open drain systems (Site A and Site B)
- closed drain systems (Site B)
- sewage treatment facilities (Site B).

Open Drain Systems: Open drain systems will be constructed at both the gas processing plant (Site B) and storage and export facilities (Site A). Separate systems will be designed to collect and direct clean water and contaminated water.

Clean water will mainly comprise stormwater and clean water runoff from hardstand areas around facilities and roads, and from firewater and water tank / drain overflows. Hardstands and pavements will be graded to permit water runoff to perimeter drain channels at the outer edges of plot areas. The open drain system will direct clean storm water via channels into ditches where it can be disposed of to natural drainage. Studies of flooding and drainage at Site A and Site B will be undertaken, and drainage will be designed to incorporate findings from the studies. Clean stormwater will be directed away from the onshore facilities to prevent flooding.

Separate open drain systems will also be installed for non routine contaminated water that is intentionally produced (for example, demineralised hot water or contaminated washdown water discharged during maintenance) and AOC water (for example, from spills). Bunded drains will be provided for equipment that could leak lube oil, diesel or other substances, and bunds will contain small collection sumps located around equipment. Other areas, such as workshops, will also have drainage systems for contaminated water. Non routine contaminated water and AOC water will be directed to and held in a retention basin, from where it will undergo treatment. The treated water will be disposed of via a marine discharge pipeline. Details of the water treatment and discharge specifications from the waste water treatment facility are provided in **Section 5.2.15**. Consideration of alternatives to marine disposal of treated AOC water and other waste water generated during operations is discussed in **Section 3.6**.

Closed Drainage System: The processing plant will be provided with a closed-loop drainage system to collect hydrocarbon liquids. The hydrocarbon liquids will be routed to the wet flare knock-out drum prior to flaring. An electric strip heater will be provided on the outside bottom of the knock-out drum to vaporise any liquid knock-out.

Sewage Treatment Facilities: Dedicated sewage treatment facilities will be provided at Site B during operation. Treated sewage from Site B will be disposed of via a marine discharge pipeline (**Section 5.2.15**). The management and disposal of sanitary wastes during construction and operation is discussed in **Section 5.2.15**. Consideration of alternatives to marine disposal of treated sewage during operations is discussed in **Section 3.6**.

4.7.7 Utilities Description

The gas processing plant at Site B will be self-sufficient in terms of utilities. All required utilities at the storage and export facilities (Site A) will be imported from Site B with the exception of drinking and service water and firewater. Preliminary studies have indicated that at least the following systems will be required as a minimum:

- *Electricity Generation:* Electrical power generation will be sufficient to meet the demands of the gas processing plant at Site B and the storage and export facilities at Site A. Total demand will be met using low NO_x gas turbine generators, fired by fuel gas from the onshore facilities.
- *Diesel*: Firefighting systems such as firewater pumps within the processing facility at Site B will be equipped with a back-up/emergency diesel system complete with storage tank, transfer pumps, filter/coalescer and distribution system. The distribution system will supply all required diesel day tanks (24 hour demand) for equipment requiring diesel such as fire water pumps. Diesel will be imported to the process facility by road tanker.

4.8 Commissioning and Start-up Activities

Commissioning will be undertaken for both onshore and offshore infrastructure at different times. The purpose of this activity will be to confirm that all equipment functions properly and safely and that there are no leaks detected within the various systems.

Prior to start-up, detailed procedures will be in place and made available to personnel regarding the operations, inspections and maintenance of all facilities. A general description of commissioning activities is outlined below.

4.8.1 Offshore Development

4.8.1.1 Subsea Wells, Flowlines and Platform

It is anticipated that commissioning of wells, flowlines and the offshore riser platform will be undertaken in 2010. Commissioning will include testing, adjusting and monitoring of the following systems and facilities:

- wellhead controls
- safety systems
- flowlines and support systems
- control systems and communication systems
- power and utility systems
- chemicals storage facilities
- pumping systems.

Commissioning of these systems involves testing the systems and undertaking any adjustments to ensure normal operating performance. Most of these systems will be commissioned on site, with the exception of the platform topsides which will be commissioned offsite.

4.8.1.2 Gas Trunkline

The gas trunkline will be hydrotested and dewatered under controlled conditions. The trunkline will be filled and emptied from the offshore end. The volume of hydrotest water discharge for the gas trunkline will be dependant upon the trunkline route selected and also on the trunkline diameter size. Preliminary estimates, based on a 42" trunkline diameter, are up to 153 000 m^3 of hydrotest water. Hydrotesting may be undertaken in a single section or as a series of sections. Following hydrotesting, the trunkline will need to be dewatered to make way for production fluids. De-watering will be carried out by propelling pigs through the trunkline to the riser platform with compressed air from the onshore end. It is anticipated that dewatering will be undertaken as a single operation for each section of trunkline, flowline and supply line. The hydrotest water (comprising filtered seawater with additives including oxygen scavenger, biocides, corrosion inhibitor, scale inhibitor and fluorescent dye for leak detection) will be discharged to the ocean at the offshore riser platform location. The onshore section of the trunkline may or may not be tested with the offshore section (**Section 4.8.2.1**). Hydrotest water is discussed further in **Section 5.2.11**.

4.8.2 Onshore Development

4.8.2.1 Onshore Pipelines

Standard onshore pipeline commissioning techniques will be applied, including hydrotesting to determine the strength and leak tightness of test sections. Hydrotesting specifications will be determined closer to the commissioning period. After testing is complete the pipelines will be dewatered, using propelled pigs, and dried.

The onshore pipeline section could be hydrotested independently of the offshore section; alternatively, the offshore and onshore sections of the trunkline may be filled and hydrotested as one complete system with water sourced from and discharged at the offshore end (**Section 4.8.1.2**). The disposal of hydrotest water is discussed in **Section 5.2.11**.

4.8.2.2 Gas Processing Plant

Commissioning of the gas processing plant and associated systems is required for the testing and adjustment of equipment, introduction of reservoir fluids and start-up of production. During start-up, which is a non-routine event, plant throughput can vary from 15% to 50%. Flaring of gas will be continuous during this period as the system will be too warm to produce LNG product. This process will be repeated for the commissioning of each LNG train.

Commissioning involves a number of activities including:

- start-up of ancillary systems such as power generators, fuel gas systems, drainage systems, safety and control systems
- start-up of air coolers
- start-up of flare and relief systems
- testing of turbines and compressors
- pressure testing on inlet area
- testing and start-up of the amine system (including use of a caustic wash to remove grease) and molecular sieve dryers
- drying out of the liquefaction process system
- operation of the gas processing plant and LNG/condensate production
- loading of first LNG tanker
- completion of performance testing.

As part of these commissioning activities a series of tests will be undertaken to demonstrate that all individual systems within the gas processing plant perform according to design specifications. These tests will need to be completed before performance testing can be conducted to prove the plant capacity, fuel efficiency and LNG production rate.

4.8.3 Storage and Export Facilities

Either filtered seawater or freshwater will be used to hydrotest the LNG and condensate tanks at Site A. It is anticipated that the volume of water required for hydrotesting will be similar to the volume of one LNG tank, and will be re-used in testing. Hydrotest water will be diverted to the water treatment plant once commissioning is complete, and will either be reused or discharged after treatment. The flare located at Site A will be tested as part of commissioning activities.

4.9 Production and Operation

4.9.1 Offshore Development

4.9.1.1 Re-drilling

There may be a requirement to undertake re-drilling of existing wells when the Pluto LNG Development is operational to maintain production capacity and integrity. Future re-drilling is only expected to be required in the event that the sand screens inserted into the wells fail to prevent unconsolidated, loose sand from clogging the bottom of the well. Under these circumstances the well may need to be replaced. Similarly, access to the well may be required should the well integrity be compromised, for example through the failure of subsurface isolation valve.

4.9.1.2 Subsea Control and Monitoring

The subsea production wells, flowlines and manifolds will be routinely monitored during operations. The subsea control and monitoring scheme for each of the development concepts under consideration will be similar and will broadly consider the following:

- well downhole gauges will measure reservoir pressures and temperatures
- provision of wet gas meters to measure well flows using virtual metering techniques at the subsea tree
- subsea control system integrity monitoring to measure insulation resistance in subsea umbilicals
- onshore / offshore communications system.

It is likely that ROVs, drill rigs and support vessels will be used for the periodic inspection and maintenance of subsea wells, flowlines and manifolds. These inspections will monitor the exterior surface of subsea facilities and will identify any issues associated with seabed integrity.

Subsea equipment will be controlled by an electro-hydraulic control system fed by the umbilical from the platform. The hydraulic fluid is a glycol / water based chemical. The hydraulic control system will be ‘open loop’ which will entail some discharge to the ocean during valve actuation.

4.9.1.3 Gas Trunkline and Flowline Maintenance

The gas flowlines and trunkline will require maintenance, which may include:

- *Internal Pigging* – as a wet trunkline, the trunkline will require inspection pigging to demonstrate that corrosion risks are being managed in accordance with a risk-based inspection philosophy that will be developed as part of a Pipeline Management Plan.
- *Corrosion Management* – periodic pigging may be required to assist corrosion management by distributing corrosion inhibitors, displacing stagnant water and removing deposited solids, although this is considered unlikely.
- *Liquid Management* – operational strategies will try to limit accumulation of liquids under all operational conditions. Additional actions may be required to limit liquids under unusual severe turndown scenarios. These include pigging of the trunkline, or periodically gas sweeping the fluids through the flowlines.

Pigging operations may also be performed on the deep water flowlines, particularly for inspection and corrosion management, should carbon steel flowlines be selected.

4.9.2 Nearshore Development

During operations it is anticipated that the frequency of LNG vessel exports will be approximately once every five days. Given the low volume of condensate contained within the wet gas, condensate export will be very infrequent, with exports anticipated to occur only four times a year.

Up to four support tugs will be required to safely assist tankers during approach and departure operations. The tugs will be berthed at either one of the existing supply bases or a new multi-user supply base.

The marine export facilities will be designed to operate on a 24 hour basis for 360 days a year, however, this operating approach will be modified in the event of a cyclone or when maintenance is required for loading equipment and / or the jetty structure.

4.9.2.1 LNG and Condensate Loading

The LNG and condensate will be exported from the same mooring on the export jetty. Navigational aids and berth aid systems will be provided during operation to allow safe and efficient loading of products.

Loading facilities will operate in holding mode (the period of time between loadings) and in loading mode (the period when a ship is on berth and receiving LNG or condensate). During loading operations LNG will be transferred to a berthed vessel using pumps and two loading arms, with two separate liquid/ vapour return arms. An LNG vapour return line will transfer LNG vessel vapours to the boil-off gas compressor located onshore. The loading of LNG vessels will result in the production of methane gas within the LNG storage tanks caused by a combination of heat differential and the displacement of liquids as the tanks are filled. This gas will be recovered by the boil-off compressors located at Site A and returned to the liquefaction system at Site B.

Vapours are also produced during the cool down of the LNG loading lines, which are displaced from the vessel during loading operations. A proportion of these vapours are used to displace the LNG removed from the tank during loading. The remainder of the vapours will be sent to the boil-off gas compressor and transferred to Site B.

A mooring load monitoring system will be provided which will include an audible alarm for leak detection and a display of load parameters.

4.9.3 Onshore Development

4.9.3.1 Gas Processing Plant

The operation of the plant is described in **Section 4.7.3**. The plant will be designed for an operational life of 30 years and will operate continuously, except during shut-down periods or emergency events. The facilities will operate during cyclone events, as is the case of the existing NWSV Karratha Gas Plant but there may be a requirement for unplanned shut-down events, should the processing plant operate outside of its design limits. Shut-down could be either manually activated or triggered by automatic safety instrumentation. During shut-down events, flaring will be undertaken.

During operations, the onshore plant will require a permanent workforce of approximately 150 personnel. The workforce is likely to be accommodated in Karratha or Dampier.

4.9.3.2 Storage and Export Facilities

The storage and loading facilities at Site A will not normally be manned, except during product load out operations. The flare at Site A will be used during loading operations to relieve pressure in the tanks and return lines, only in the rare event that either the boil-off gas compressors are not operational or an LNG ship has returned from a shipyard containing inerted vapours such as nitrogen rather than LNG (methane) vapours. Vapours within a ship's hold such as nitrogen need to be removed prior to loading.

The tanks, boil-off compressors and associated facilities at Site A will require routine maintenance and inspection.

4.10 Decommissioning and Abandonment

The exact decommissioning and abandonment requirements will be agreed with the regulatory authorities closer to the time of decommissioning. Decommissioning of the Pluto LNG Development will consider the following:

- The condition of the existing marine and terrestrial environments.
- The International, National and State regulatory legislation and standards at the time of decommissioning – including the International Maritime Organisation (IMO) Guidelines and standards for the Removal of Offshore Installations and Structures in the Continental Shelf and in the Exclusive Economic Zone (Resolution A, 672(16)) (1989), the *Environment Protection (Sea Dumping) Act 1981* (Cwth), the EPBC Act, the EP Act and the *Petroleum (Submerged Lands) Acts* (WA and Cwth) and related regulations.
- Health and safety legislation and standards.
- Other relevant guidelines.

It is likely to be economically and environmentally preferable to leave certain project infrastructure in-situ, for example, it is anticipated that subsea flowlines, the trunkline and other buried pipelines (MEG supply line and water disposal lines) will be cleaned, flushed and left in-situ. It is anticipated that other systems and facilities will be removed and rehabilitated, for example the onshore gas processing plant and access roads. In such cases, all health, safety and environment issues will be addressed and the appropriate government departments consulted on the proposed approach.

Emissions, Discharges and Waste

5

5.1 Atmospheric Emissions and Pollutants

5.1.1 Greenhouse Gases

5.1.1.1 Overview

Development of the Pluto gas field will result in greenhouse gas emissions over the life of the development; comprising both direct emissions from the production of LNG and other lifecycle emissions that include emissions from the use of the LNG, for example electricity generation in other countries.

Based on LNG production of 5.9 Mtpa the estimated direct emissions for the Pluto LNG Development are in the order of 1.9 Mtpa of CO_2e (carbon dioxide equivalent) increasing to approximately 4.1 Mtpa of CO_2e when LNG production increases to 12 Mtpa (the greenhouse gas emissions are based on 95% plant utilisation). The increase in greenhouse gas emissions is a result of a second LNG train coming on line and also the assumption that offshore compression will be required for the Pluto gas field after 4-10 years of project operations.

Woodside has already achieved significant emission reductions on 'business as usual' projections (based on Karratha Gas Plant 2000) and continues to invest in a range of abatement measures.

In addition, when a life cycle approach is adopted, electricity generated using LNG has a significantly reduced GHG impact compared to electricity generated using coal or oil.

The Western Australian Government recognises the important role LNG fulfils as a transition fuel and this is formalised in the Western Australian Greenhouse Strategy (WA Greenhouse Taskforce, September 2004). A key initiative within this document is a commitment to develop a Strategic Energy Resource Policy, which seeks to "encourage the long term export of relatively cleaner fossil fuels such as LNG" (WA Greenhouse Strategy, Action Item 4.9).

5.1.1.2 Greenhouse Gas Emissions

Each of the identified greenhouse gases has a different potential impact on atmospheric heat absorption based on their relative abilities to absorb energy and respective lifetimes in the atmosphere. To provide a means of standardising the relative impacts of emissions of various greenhouse gases, a Global Warming Potential (GWP) was developed to describe the contribution of each gas relative to an equal quantity of CO_2. Methane has a GWP of 21; hence, one tonne of methane released to the atmosphere is equivalent to releasing 21 tonnes of CO_2. The GWPs used in this Draft PER are consistent with the Inter-governmental Panel on Climate Change (IPCC 1996) and are listed in **Table 5-1**.

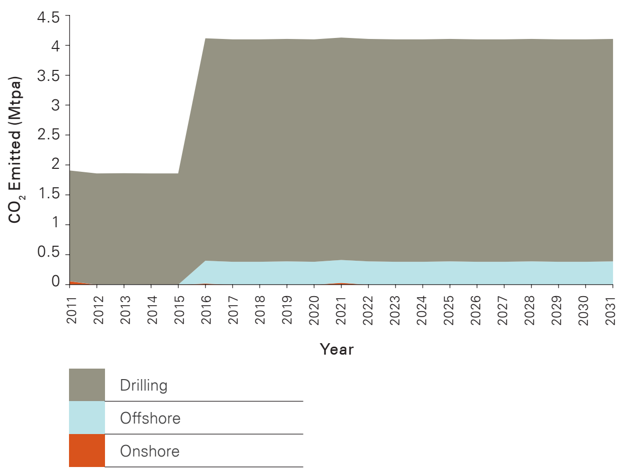
Figure 5-1 presents the expected emissions profile for the Pluto LNG Development. It is anticipated that (after 4–10 years of operation) offshore gas compression facilities and the start-up of the second onshore LNG train at Site B will be required. At this point the greenhouse gas emissions are anticipated to increase to 4.1 Mtpa of CO_2e based on the current design and a capacity utilisation of 95%. The timing of offshore compression will be dependent on the rate of decline of the Pluto gas reservoir pressure and therefore has the potential to be significantly delayed if the reservoir has greater gas reserves than expected or additional gas fields are tied into the platform.

Table 5-1 Global Warming Potential of Different Gases Relative to CO_2

Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Perfluorocarbons	6 500 – 9 200
Hydrofluorocarbons	140 – 11 700
Sulphurhexafluoride	23 900

Source: IPCC (1996)

Figure 5-1 Greenhouse Gas Emissions Profile



As shown in **Figure 5-2** greenhouse gas emissions from the gas processing plant will be dominated by three major emission sources:

- liquefaction (47%)
- power generation (32%)
- Acid Gas Removal Unit (AGRU) (18%).

Gas turbines are used to drive the main liquefaction compressors and for power generation.

The AGRU removes the CO_2 that is naturally occurring in the feed gas (approximately 2 mol %). This CO_2 needs to be removed so it does not freeze during the LNG liquefaction process and damage the main cryogenic heat exchanger. The removed CO_2 is then vented to the atmosphere. Vented CO_2 is proportional to LNG production rate.

Other onshore greenhouse gas emission sources include:

- flaring (2%)
- nitrogen rejection vent (1%)
- MEG regeneration and fugitive emissions (combined less than 1%).

Figure 5-2 Onshore and Offshore Emission Sources Averaged Over First 20 Years

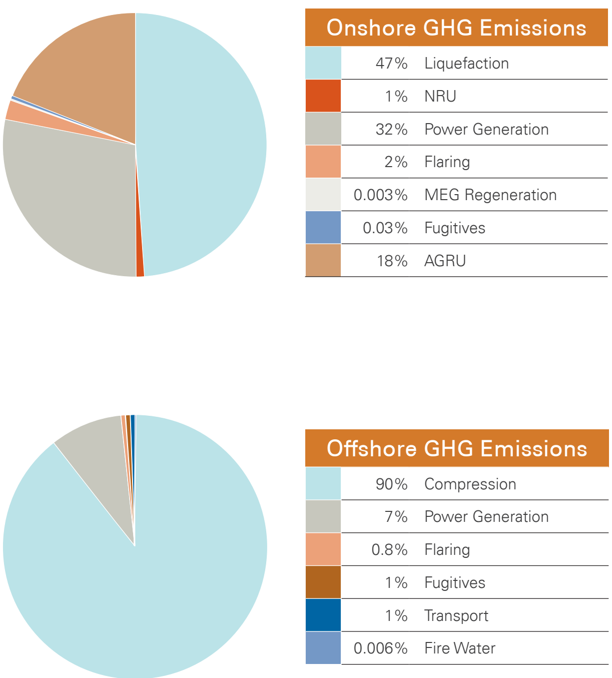


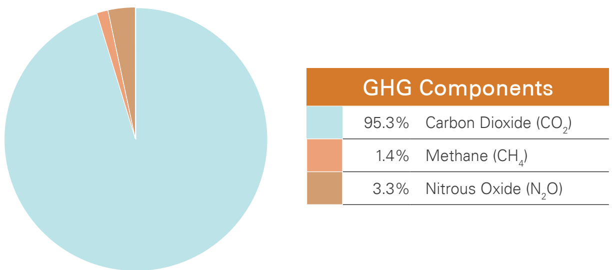
Table 5-2 provides an estimate of the onshore greenhouse gas emissions for the proposed Development. The greenhouse gas emissions calculations are averaged over the first 20 years based on producing a total of 5.9 Mtpa until year five and 12 Mtpa of LNG thereafter.

Table 5-2 Estimated Annual Onshore Greenhouse Gas Emissions Averaged Over First 20 years

Source	Greenhouse Gas Emissions ($kT\ CO_2\ e$)
Liquefaction Gas Turbines	1534
Power Generation Turbines	1062
AGRU (CO_2 Removal) Vent	574
Flaring	65
Nitrogen Rejection Vent	36
Fugitive	1
MEG Regeneration	0.1
Total	3271

Figure 5-3 shows the breakdown of greenhouse gas emitted from the gas processing plant. As the graph demonstrates, greenhouse gas emissions primarily consist of CO_2 with a small contribution from N_2O and CH_4 contributing about 5% to the CO_2e emissions.

Figure 5-3 Greenhouse Gas Components (CO_2e basis) – Onshore Facilities



Onshore construction emissions are anticipated to be in the order of 200 000 tonnes of CO_2e. However, this should be considered as an order of magnitude estimate as the facility design process is ongoing and details of construction activities are still under development.

As shown in **Figure 5-2** greenhouse gas emissions from the offshore platform will originate from two main sources:

- compression
- power generation.

Minor emissions can also be expected from fugitive emissions sources such as flanges and valves, flaring and transport.

Table 5-3 provides an estimate of the emissions expected from the offshore riser platform. Offshore compression is anticipated to be required 4–10 years after commissioning. Offshore compression will probably require a manned platform and large gas turbines to compress the gas into the export trunkline, in order to cater for reservoir depletion.

Table 5-3 Average Annual GHG Emissions – Offshore Facilities

	Pre Offshore Compression (tonnes CO_2e)	Post Offshore Compression (tonnes CO_2e)
Power Generation	600	21 700
Flaring and venting	1500	2400
Fugitive	600	2300
Transport	750	3200
Compression	-	265 600
Fire Water		20
Total	3450	295 220

Optimisation of compression timing and design will have the most significant impact on overall offshore emissions. The timing of compression may be delayed if additional reserves are tied into the platform enabling the required feed gas rate to be maintained longer without the need for compression.

The identified flaring and venting emissions allow for upset or emergency conditions as there will be no process flaring under standard operating conditions beyond normal purging and pilot system to ensure safe flare operation.

Under certain circumstances, such as maintenance or unplanned depressurisation, it may be necessary to vent rather than flare gas. These events are not expected to contribute significantly to greenhouse gas emissions. Due consideration will be given to the technical feasibility of flaring in relation to the scale and frequency of these events.

Offshore and marine construction emissions are anticipated to be in the order of 470 000 tonnes of CO_2e and drilling will contribute a further 50 000 tonnes of CO_2e. As with onshore construction emissions, these should be considered as order of magnitude estimates as the facility design process is ongoing and details of construction activities are still under development.

Greenhouse gas emissions were calculated in a manner consistent with the methodology used by the National Greenhouse Gas Inventory Committee and Woodside's reporting framework under the Greenhouse Challenge Program. The CO_2 emission factors utilised were corrected against the carbon content of the natural gas to be combusted within the facility.

5.1.1.3 Greenhouse Gas Management

Greenhouse Gas Management Planning

Woodside is committed to the reduction of greenhouse gases for the proposed Pluto LNG Development. To meet this commitment the following activities are being undertaken:

1) ensure greenhouse gas and energy efficiency of design, by:
   - assessment of greenhouse gas emissions in all key design decisions and technology selections
   - energy efficiency review of the design
2) review opportunities for continuous improvement of technological and operational practices to reduce greenhouse gas emissions during operations.
3) encourage the long-term export of LNG which is cleaner and has lower lifecycle greenhouse gas emissions relative to other fossil fuels in a manner consistent with the Western Australian Greenhouse Strategy (Chapter 4, Action item 4.4)
4) consider alternative means of emissions abatement such as external greenhouse gas offset opportunities.

Actions arising from these activities will be implemented within the broader development constraints such as safety implications, technical feasibility/risk, project viability, schedule constraints and other environmental considerations.

5.1.1.4 Energy Efficiency of Design

Increasing the energy efficiency of LNG facilities is a key goal of the design process. Wasted energy results in the use of fuel gas that could otherwise be sold as LNG. This provides a natural driver to assist in the reduction of greenhouse gas emissions from a gas processing plant. The following section discusses the key sources of greenhouse gas emissions and how Woodside is approaching their minimisation.

A review of the efficiency of the proposed design will be undertaken by the design team. This review will provide an opportunity to identify areas where energy savings could be made leading to reductions in fuel gas consumption which in turn will result in less greenhouse gas emissions.

One key aspect of minimising greenhouse gas emissions is to ensure stable operations. Stable operations ensure that the relatively high emissions related to plant start-up and shut-down are minimised as well as maximising facility production. Only proven technology is typically considered for LNG plants in order to achieve stable operations.

Acid Gas Removal Unit (CO_2 Removal) Vent

The Pluto gas reservoir has a naturally occurring CO_2 content of approximately 2 mol% based on the wells drilled to date. For the emission estimates a CO_2 content of 2 mol% has been used. This CO_2 has to be removed from LNG so that it does not freeze solid within the cryogenic equipment. This is achieved using a solvent which is contacted with the gas stream within the AGRU. This solvent is then regenerated in two stages by:

- flashing to a lower pressure releasing some of the absorbed gases, primarily composed of hydrocarbons (often referred to as 'flash gas')
- heating the solvent in the regenerator column to drive off the CO_2 which is vented to the atmosphere.

To minimise hydrocarbon emissions from the AGRU in the second stage of the regeneration process, aMDEA has been selected as the preferred solvent. The advantage of aMDEA is that it absorbs significantly less hydrocarbons in the process of absorbing the CO_2 out of the feed gas stream. This reduces the quantities of hydrocarbons flashed or vented from the regenerator column during the heating process. The vented CO_2 stream is passed through a thermal oxidiser to ensure that any remaining hydrocarbons are converted to CO_2 which has a lower GWP. The thermal oxidiser will remove approximately 98% of BTEX from the feed gas. In the event that the thermal oxidiser is not operational, any BTEX in the feed gas will be vented to atmosphere.

The first stage of the solvent regeneration is flashing to remove the co-absorbed hydrocarbons. Although the use of aMDEA reduces the quantity of this flash gas, Woodside is committed to recovering this gas and utilising it within the process to ensure that it is not vented or flared.

Waste Heat Recovery

The AGRU also represents the largest heat demand within the gas processing plant. This heat demand will be met from waste heat recovered from the liquefaction turbines. Recovered waste heat eliminates the need for operational boilers which would be an additional source of greenhouse gas emissions.

Other heat loads that will utilise waste heat include the fuel gas heater and condensate stabilisation heaters. The majority of the heat requirements of the MEG regeneration will also be met from recovered waste heat. In this manner all the major heat demands will be met during normal operation by recovered waste heat.

Liquefaction Process

The liquefaction process is at the core of the gas processing plant and is the largest energy user. Woodside has included greenhouse gas and energy efficiency as one of the key assessment criteria in the selection of LNG technology. The turbines within the liquefaction process (used in the refrigerant loops) will be matched to the refrigeration load in order to maximise operational efficiency.

Nitrogen Rejection Vent

The last stage of the LNG process prior to discharge into the LNG storage tanks is removal of the excess nitrogen. This is achieved by flashing the LNG down to atmospheric pressure and recovering the flashed gas to a nitrogen package. This package will recover the associated hydrocarbon gas to ensure that the vented stream has approximately 0.2 mol% hydrocarbons (predominately CH_4). This will be achieved via a cryogenic fractionation process.

The recovered hydrocarbons from this nitrogen removal process will be used for fuel gas within the Pluto LNG Development. Utilising this waste gas with a high nitrogen content for fuel rather than sending it to flare ensures that the energy contained in the gas is recovered and used as fuel for the liquefaction turbines, reducing greenhouse gas emissions.

Power Generation Turbines

Power generation for the onshore facilities will be provided by five Frame 6 turbines. The key parameters that go into the selection of the final turbine configuration include reliability, stability and matching of loads to turbine configuration. All of these attributes assist in reducing the overall greenhouse gas emissions of the facility.

The other aspect impacting the emissions from the power turbines is the total electrical demand for the gas processing plant. The electrical demand is in part determined by the overall design efficiency discussed throughout this section.

Flaring

The design basis for the gas processing plant is that there will be no operational flaring for the Pluto LNG Development. To achieve this, the following measures will be implemented:

- boil-off gas compressor sized to recover boil-off gas from the LNG tanks during holding mode and for full recovery of vapours during ship loading (that is, vapours from both the LNG tanker and LNG storage tanks)
- recovery of waste gas streams either back to the process or into the fuel gas system
- maximisation of the reliability and stability of the gas processing plant to minimise process and safety trips causing depressurisation of the facility to flare.

For safety reasons the flare will be required to be purged with fuel gas to ensure that oxygen does not propagate down the flaring header creating an explosion hazard. Several pilots will also be required to ensure the ignition of gas during an emergency when the flare is required.

Further opportunities will be reviewed to minimise quantities of gas flared during the detailed design of the facility and the flare system.

Fugitive Emission Sources

Within a modern LNG facility, fugitive emissions are a relatively minor contributor to greenhouse gas emissions. Some of the design principles and features that contribute to this are:

- elimination of leak sources (for example, using welded connections and minimising valves and flanges where practicable)
- specification of dry gas seals on the large liquefaction compressors which virtually eliminates the seals as a source of emissions
- floating roof tanks for condensate storage
- fugitive leak inspection programme.

Offshore Facilities

During the design and operational phases the following management measures shall be put in place for the management of greenhouse gas emissions for the offshore platform:

- An energy efficiency review of the platform design will be conducted.
- Facility reliability will be a key design premise to minimise process upset type conditions that lead to additional flaring.
- Flaring and venting events will be minimised to as low as reasonably practicable (ALARP).
- Design and technology selection for future offshore compression facilities shall include greenhouse gas emissions as a key factor.

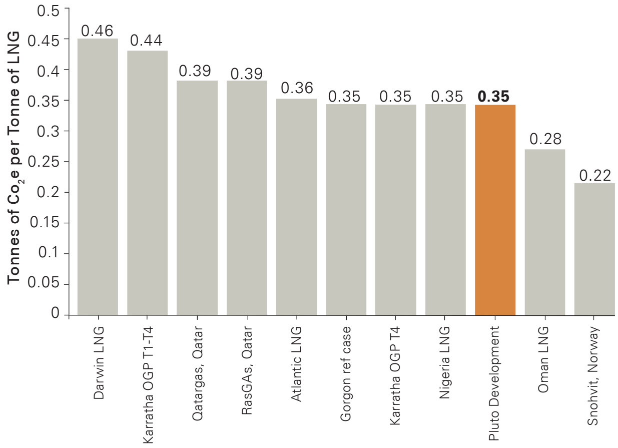
5.1.1.5 Comparative Greenhouse Gas Emissions of the Pluto LNG Development

Benchmarking of a gas processing plant is difficult to undertake due to the proprietary nature of data relating to plant performance and the differences in greenhouse efficiency that occur due to local factors. The overall greenhouse gas emission intensity can be influenced by:

- the composition of the raw gas steam coming into the gas processing plant, in particular the concentration of the reservoir CO_2
- the ambient temperature at the gas processing plant location (lower temperatures improve cooling and turbine efficiency)
- the level of integration with other gas processing facilities such as domestic gas supply, LPG extraction and condensate (light oil) production.

Based on available data, the reference case for the onshore portion of the Pluto LNG Development has been benchmarked against recent LNG developments. All of the benchmarked LNG developments have been constructed within the last five years with the exception of the Karratha Gas Plant where LNG Trains 1–3 were constructed over the period 1989–1992 and LNG Train 4 was commissioned in 2004. **Figure 5-4** presents the benchmarked data.

Figure 5-4 Greenhouse Gas Emissions Benchmarking



Note: The 'Karratha OPG T1-T4' greenhouse gas index incorporates all four LNG trains – Karratha OGP T4 is the greenhouse gas index if Train 4 is considered in isolation.

To enable the Pluto LNG Development to be accurately compared to Oman LNG, it is necessary to correct the estimated Pluto onshore gas processing plant emissions for the higher CO_2 content within the feed gas (**Table 5-4**). The Pluto reservoir has approximately 2 mol% CO_2 naturally occurring within the reservoir compared to Oman LNG with approximately 1.0 mol% CO_2. If the Pluto LNG Development greenhouse gas efficiency is recalculated for the lower reservoir CO_2 content, the resulting efficiency is 0.32 tonnes of CO_2e per tonne of LNG.

Similarly the conditions at Statoil's Snohvit LNG development lead to a higher greenhouse gas efficiency. Snohvit is located on the Barents Sea in Norway above the Arctic Circle (71°N) with an average ambient temperature of approximately 0°C. This cooler ambient temperature combined with their commitment to re-inject reservoir CO_2 results in a facility with higher greenhouse gas efficiency.

Table 5-4 Reservoir CO_2 Content

LNG Facility	Reservoir CO_2 Content
Gorgon – Barrow Island	14 mol% (Gorgon) <1 mol% (Io Janz)
Snohvit, Norway	8.0 mol%
Darwin LNG	6.0 mol%
Karratha Gas Plant	2.5 mol%
RasGas, Qatar	2.3 mol%
Qatargas, Qatar	2.1 mol%
Pluto LNG Development	2 mol%
Nigeria LNG	1.8 mol%
Oman LNG	1.0 mol%
Atlantic LNG	0.8 mol%

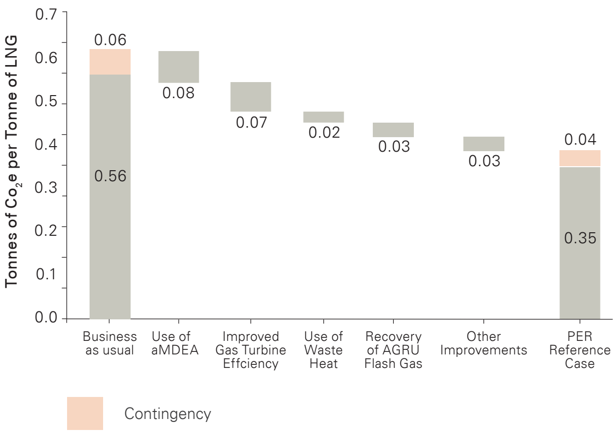
Table 5-5 compares the total estimated Pluto LNG Development greenhouse gas emissions (both offshore and onshore emissions **Section 5.1.1.2**) with Australia's and Western Australia's 1990 baseline greenhouse gas emissions.

Continuous Improvements

Woodside is committed to continually reviewing the facilities it operates for potential greenhouse gas improvements. Some of the projects implemented to improve greenhouse gas performance by Woodside, as the operator of the various facilities, are outlined in **Section 5.1.1.7**. This commitment will continue throughout the construction and operation of the Pluto LNG Development.

Figure 5-5 shows the key design improvements that have been incorporated into the Pluto LNG Development, as presented in this Draft PER. The 'business as usual' case is based on the calculated greenhouse efficiency of a Pluto LNG Development utilising similar technology and process design that existed in the Karratha Gas Plant in 2000.

Figure 5-5 Greenhouse Gas Emissions Efficiency Improvements



5.1.1.6 Life-Cycle Benefits of LNG

When assessing the greenhouse gas impacts of fuel sources the entire life-cycle of a fuel should be considered from production through to consumption. This approach is referred to as life-cycle greenhouse analysis. Life-cycle emissions include emissions relating to the extraction, processing, distribution and the combustion of the fuel by the end user. This therefore represents the full greenhouse gas impact of a fuel, rather than concentrating on the emissions relating to only one aspect, for example, production.

Comparison of various fossil fuels has consistently shown that the use of natural gas or LNG for energy production produces the lowest greenhouse gas output per unit of energy. For example, the United Kingdom significantly reduced its greenhouse emissions during the 1990s by switching its primary electricity generating fuel from coal to natural gas. This resulted in a reduction to its greenhouse emissions from power plants by 29% between 1990 and 1999 despite a 16% increase in electricity consumption (Department for Environment, Food and Rural Affairs 2001).

Figure 5-6 shows the lifecycle benefits of LNG compared to alternative fossil fuels for power generation in Japan (based on the 1996 CSIRO study 'Lifecycle Emissions and Energy Analysis').

5.1.1.7 Alternative Emissions Abatement Opportunities

Geosequestration

Woodside is continually reviewing new technology to reduce emissions. One such technology that shows potential for the LNG industry is carbon geosequestration. Carbon geosequestration involves recovering a concentrated CO_2 stream, compressing the CO_2 to a supercritical state and injecting it into a suitable subsurface reservoir. Woodside is a strong supporter of the Cooperative Research Centre for Greenhouse Gas Technologies (CO_2CRC) which is undertaking geosequestration research.

Table 5-5 Comparison of Estimated Pluto LNG Development Greenhouse Gas Emissions with Australian and Western Australian Baseline Emissions

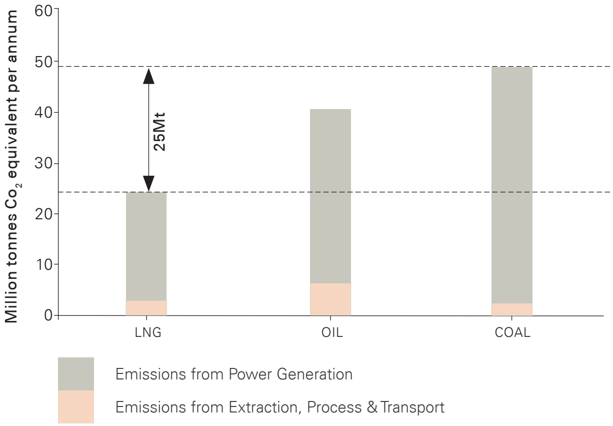
	Million Tonnes of CO_2-e	Percent relative to 1990 Baseline
Australia 1990 Baseline Emissions[1]	551.9	
Pluto LNG Development – Pre-Offshore Compression	1.9	0.34
Pluto LNG Development – Post-Offshore Compression	4.1	0.74
Western Australia 1990 Baseline Emissions[2]	57.3	
Pluto LNG Development – Pre-Offshore Compression	1.9	3.3
Pluto LNG Development – Post-Offshore Compression	4.1	7.2

Notes:

1. National Greenhouse Gas Inventory 2004 -Australian Greenhouse Office, Department of the Environment and Heritage, May 2006. (Kyoto accounting framework).

2. State and Territory Greenhouse Gas Inventories 2004 -Australian Greenhouse Office, Department of the Environment and Heritage, May 2006. (Kyoto accounting framework).

Figure 5-6 Lifecycle Emissions of Fossil Fuels



Based on 8 Mtpa of LNG production per annum generating 60 million MWh of electricity

An integral part of the LNG process is the removal of naturally occurring CO_2 from the feed gas. The concentrated CO_2 resulting from this process is a candidate for geosequestration.

Potential reservoirs for geosequestration include the Wandoo, Harriet-Campbell group of fields and the North Rankin - Goodwyn fields. However, all of these reservoirs are located in excess of 60 km from the Burrup Peninsula and are currently producing oil and gas fields. As a result, these fields would not be available for geosequestration until later in the life of the Pluto LNG Development. Furthermore these fields are all located offshore and would require the use of a subsea trunkline for transport of the CO_2.

Given that reservoir CO_2 contributes only approximately 15% of the total Development's greenhouse emissions, lack of availability of suitable reservoirs, the relatively low CO_2 content of the Pluto gas field (that is, approx. 2 mol%) and high cost of injection, geosequestration is not considered a reasonably practicable option for the Pluto LNG Development. However, Woodside is committed to investment into geosequestration research and will continue to review opportunities for its application.

External Emission Abatement Opportunities

Woodside is committed to investing in opportunities that have the potential to provide greenhouse gas abatement. At a corporate level, Woodside will continue to review and invest in suitable external opportunities that have the potential to abate emissions.

As part of the development of the Greenhouse Gas Management Plan (**Table G-5**, **Appendix G**), consideration shall be given to the use of external greenhouse gas abatement opportunities. This may include investment in sequestration through forestry or investment in other opportunities that result in reduced greenhouse emissions.

5.1.1.8 Woodside's Commitment to Greenhouse Gas Management

Woodside supports the global effort to reduce greenhouse emissions and accepts it has a responsibility to minimise the greenhouse impact of its own operations. Woodside has already achieved significant emission reductions on business as usual projections and continues to invest in a range of abatement measures.

Greenhouse Gas Abatement Projects

Woodside has been a member of the Australian Government's Greenhouse Challenge Program since 1997. Woodside and its joint venturers have completed and planned abatement actions which will result in approximately 40 million tonnes CO_2e of abatement (on the basis that each abatement project operates for 20 years) at a cost of A$167 million. In addition to paying its share of the cost of abatement (about A$61 million), Woodside has also invested A$58 million in sustainable and renewable energy technologies through its wholly owned subsidiary Metasource Pty Ltd. This brings Woodside's total spending on abatement and sustainable and renewable energy investments to A$121 million. Greenhouse gas abatement projects have included:

- The flash gas project at the Karratha Gas Plant: This project took natural gas from the LNG process that was being wasted and used it as fuel, with savings of about 570 000 tonnes of CO_2e per year. This project won an award from the Australian Greenhouse Office in 2001.
- In 1993 structured packing (a honeycomb like metallic structure), over which the Sulfinol spreads in a thin film, thus enhancing absorption of the CO_2 replaced conventional trays in the Sulfinol absorber columns of LNG Trains 1 and 2 at the Karratha Gas Plant. This facilitated a change in Sulfinol composition, significantly reducing the amount of co-absorbed methane. If structured packing had not been introduced, greenhouse emissions from operation of LNG Trains 1 to 3 on a CO_2e basis would have been approximately 20% greater than they are today.
- Solvent change project: Woodside and its joint venturers are replacing the solvent used for removing CO_2 from natural gas at the Karratha Gas Plant. As well as reducing greenhouse emissions from three existing LNG trains by approximately 350 000 tonnes CO_2e per annum (equivalent to 7 million tonnes of CO_2e over the life of the project), the new solvent will result in less air emissions and more production. The Greenhouse Challenge Plus Large Business Award for Outstanding Achievement in Greenhouse Gas Abatement in 2005 recognised this achievement.
- At the Northern Endeavour and Legendre oil operations in Australia, Woodside is re-injecting gas that cannot be economically sold. This will prevent about 14 million tonnes of CO_2e being released to the atmosphere over the life of these projects.

As Woodside's business and greenhouse emissions grow, further abatement action will be required. Woodside's key priority is to reduce greenhouse gas emissions at source, either through energy efficiency improvements or sequestration technology solutions. Where this is not feasible, Woodside will seek to use greenhouse abatement from other sources as an offset for some of those emissions

5.1.1.9 Summary of Key Mitigation and Control Measures

To ensure that greenhouse emissions for the Pluto LNG Development are managed to ALARP, Woodside will undertake the following:

1) A Greenhouse Gas Management Plan (**Table G-5, Appendix G**) will be developed and implemented. Requirements will include:
    - inclusion of greenhouse gas emissions in all key design decisions and technology selections
    - where relevant energy efficiency review of the design
    - maximising facility reliability, thereby reducing the likelihood that gas will require flaring due to process upset
    - consideration of external greenhouse gas offset opportunities.
2) The design incorporates features into the gas processing plant including:
    - use of aMDEA in the AGRU
    - elimination of the use of boilers during normal operations
    - recovery of waste streams back to the process or for fuel, such as LNG tank boil-off gas, nitrogen vent flash gas and flash gas from the AGRU
    - specification of dry gas seals on compressors.
3) Efficient operation of the Pluto LNG Development will be achieved by:
    - minimising venting and flaring of hydrocarbons and fuel gas consumption by using procedural solutions to reduce venting, flaring and combustion of hydrocarbons to ALARP
    - minimising releases by ensuring equipment is correctly maintained.

5.1.2 Combustion Products

5.1.2.1 Overview

Significant air emissions from the Pluto LNG Development will occur during normal operations of the gas processing plant and for some hours over the course of a year during non-routine operations. These operating scenarios have been the focus of the air quality assessment presented in SKM (2006a).

The most significant air pollution emissions from the Pluto LNG Development in terms of potential air quality impacts will be from the combustion of fuel gas in the gas turbines and by flaring associated with the gas processing plant. The main (non-greenhouse gas) products of combustion of fuel gas in gas turbines, in terms of quantities produced, are carbon monoxide (CO) and oxides of nitrogen (NO_x). However, the key air pollutants in terms of risk are nitrogen dioxide (NO_2), ozone (O_3) and Particulate Matter (as particulate matter less than 10 microns diameter, or PM_{10}). Small quantities (trace amounts) of other pollutants are also emitted such as Volatile Organic Compounds (VOCs) and sulfur dioxide (SO_2). The estimated annual air emissions from point sources for the Pluto LNG Development are presented in **Table 5-6**.

In the oil and gas industry, gas is burned via flaring when it must be disposed of safely during production process. Air emissions from flaring include carbon particles, hydrocarbons (or VOCs), CO and NO_x. Pluto gas has been found to have no, or negligible, hydrogen sulfide (H_2S), therefore emissions of SO_2 are expected to be very low or non-existent.

Table 5-6 Estimated Annual Emissions from Development Point Sources

Species	Gas Turbines (tpa)	Flares (pilot flames) (tpa)	Total Estimated Emissions (tpa)
NO_x	2163.4	28.4	2191.8
SO_2	305.9	0.0	305.9
PM_{10}	0.0	4.5	4.5
CO	1380.1	155.6	1535.7
VOC	0.0	58.7	58.7
Benzene	2.7	0.049	2.8
Toluene	2.7	0.024	2.8
Ethylbenzene	1.4	0.0	1.4
Xylene	4.1	0.0	4.1
Formaldehyde	0.0	0.5	0.5
Acetaldehyde	0.0	0.05	0.05

Note: Values are based on model inputs for point sources under the 'normal' operating scenario. Values do not include emissions from venting or other sources.

5.1.2.2 Baseline Case – Existing Atmospheric Emissions

Atmospheric emissions from the largest existing sources of air pollution on the Burrup Peninsula are associated with iron ore handling and port activities near Dampier, the NWSV Karratha Gas Plant, Hamersley Power Station and Burrup Fertilisers Ammonia Plant. Other sources have been collated by the West Australian DEC into two area source databases referred to as the 'gridded source file' and 'biogenic emissions source file'. All of these sources have been included in the cumulative air quality assessment for the Pluto LNG Development.

The most significant existing air emissions for the Burrup Peninsula region are:

- the NO_x emissions from the existing Karratha Gas Plant
- dust particles as emissions of Particulate Matter 10 (PM_{10}), as described within the DEC source files, and primarily from iron ore handling activities near Dampier.

In relation to the potential for the Pluto LNG Development to cause significant additional air quality impacts, the key existing emission driver is NO_x. The NO_x emission rates of the existing sources used in the air pollution dispersion modelling (described in **Section 5.1.2.5**) are:

• Karratha Gas Plant:	
– Trains 1–3	360 g/sec
– Train 4	28 g/sec
– Train 5 (expected start-up in Q4 2008)	28 g/sec
• Burrup Fertilisers Ammonia Plant 2 x stacks	11 g/sec
• Hamersley Power Station 2 x stacks	17 g/sec

5.1.2.3 Pluto Air Emissions Case – Existing Plus Pluto Atmospheric Emissions

The air emissions data for the proposed gas processing plant are based on an annual LNG production of 2 x 5.9 Mtpa and the operating scenario under consideration, such as 'normal conditions' and 'upset conditions'.

The gas processing plant will include a combination of gas turbines used for compressing the gas and power generation, wet and dry flares, marine flare, and AGRU. The key NO_x emissions data for normal operations of the Pluto gas processing plant will be approximately 69 g/sec.

Non-routine operations associated with the gas processing plant will include start-up, shut-down, and plant de-inventory during emergencies. A non-routine operation typically lasts for several hours to days with the plant operating at reduced throughput and flaring of gas. The gas processing plant's throughput would vary between 15% and 50%, depending on the stage of the start-up or shut-down process in place.

Two non-routine scenarios were assessed, representing a one-in-30 year upset case and an annual shutdown event, with total NO_X emissions of 226 g/sec for fifteen minutes, and of 147 g/sec for up to ten hours, respectively. As the time of worst-case non-routine air emission scenarios cannot be known, air quality modelling was conducted assuming that non-routine emissions occurred over every hour of the year. This ensures that the modelling remains conservative and that the maximum ground level concentrations will be generated by the model.

5.1.2.4 Air Quality Criteria

Within Western Australia, the EPA assesses any new project in terms of emissions at stack and the resultant ambient ground level concentrations. The EPA has not prescribed local standards for ambient ground level concentrations. For these, the EPA requires that pollutants comply with the air quality standards of the National Environmental Protection Measure for Ambient Air Quality (NEPM). The key NEPM standards for the Pluto LNG Development are listed in **Table 5-7**.

In Western Australia these NEPM standards are not applied within industrial areas and residence-free buffer areas around industrial estates. In the context of the Pluto LNG Development, these standards will be applied in the residential areas of Dampier and Karratha.

Table 5-7 Relevant National Environmental Protection Standards and Goals

Pollutant	Averaging Period	Maximum Concentration		Compliance Goals for Maximum Allowable Exceedences
Nitrogen Dioxide	1 hour	120 ppb	(246 µg/m³)	1 day per year
	1 year	30 ppb	(62 µg/m³)	None
Photochemical oxidants (as ozone)	1 hour	100 ppb	(214 µg/m³)	1 day per year
	4 hours	80 ppb	(171 µg/m³)	1 day per year
Particles as PM_{10}	1 day	50 µg/m³		5 days a year

5.1.2.5 Air Dispersion Modelling

Air dispersion models combine simulations of regional and local meteorology, including coastal effects and temperature inversions, with the complex physics and air chemistry of air pollution processes, to provide the best predictions for the dispersion of air pollutants. The air quality assessment for the Pluto LNG Development utilised the CSIRO Atmospheric Research air dispersion model 'TAPM' with its 1999 meteorology dataset.

The setup and operation of TAPM for the Development, including sensitivity tests undertaken with the model setups, are described in detail in SKM (2006a). The model setup followed the approach of several previous CSIRO Atmospheric Research and other air quality studies undertaken for the Burrup Peninsula. In summary, the key inputs used in the TAPM air dispersion computations are:

- atmospheric chemistry modelling mode with NO_x, NO_2, O_3, SO_2 and Particulate Matter
- tracer mode used to determine impacts from CO, benzene, toluene, ethylbenzene, xylenes, formaldehyde, acetaldehyde and Polycyclic Aromatic Hydrocarbons (PAH) as benzo[a]pyrene
- regional gridded area emissions inventory data as provided by the DEC (*.gse as formatted by SKM for compatibility with TAPM)
- regional biogenic area emission sources (*.bse)
- background ozone level 25 ppb
- background Rsmog 0.2 g/s
- background Fine Particulate Matter (PM2.5) 5 µg/m³ (estimate for clean air)
- meteorological grids: standard four 31 x 31 grid domains with resolution 30 000 m, 10 000 m, 3000 m and 1000 m
- standard 25 vertical levels 10–8000 m height
- pollution grid (inner), 25 x 25 (omitting boundary to reduce 'edge effects'), with resolution 500 m (sensitivity tests undertaken using 4 computational grids).

The TAPM land/sea database was derived from the 9" Digital Elevation Model (DEM) data (Geoscience Australia 2002) and was modified as per Physick and Blockley (2001). This involved changing the land use category to low dense forest to increase the roughness length to 0.9 m and modifying the topography files to account for the salt evaporation ponds between Dampier and Karratha.

TAPM results have been obtained for dispersion of NO_2, O_3, PM_{10}, SO_2, and the tracer pollutants such as benzene, CO, toluene, ethylbenzene, xylenes, formaldehyde, acetaldehyde and PAH as benzo[a]pyrene, for normal and non-routine operations.

TAPM results indicate that there will be no exceedences of air quality criteria due to air emissions from the Pluto LNG Development. TAPM results are cumulative and take into account other sources of atmospheric emissions (Karratha Gas Plant, Burrup Fertilisers Ammonia Plant and Hamersley Power Station). Pollutants with predicted concentrations that begin to approach NEPM standards and goals include NO_2, O_3 and PM_{10}. Results for PM_{10} are not provided here because none of the model-predicted NEPM exceedences for PM_{10} are due to sources from the Pluto LNG Development. Furthermore, results for SO_2 are not provided, as the predicted SO_2 concentrations are insignificant in relation to the corresponding NEPM goals.

The TAPM results for normal operations are provided in **Figure 5-7** (NO_2 concentrations) and **Figure 5-8** (O_3 concentrations). There are no exceedences of the NEPM standards of 120 ppb (NO_2) and 100 ppb (O_3). These are standard modelling results intended to show the worst case hourly impacts in any year at every point on the computational grid.

Figure 5-7 TAPM results for Maximum Hourly Average NO_2 (ppb)

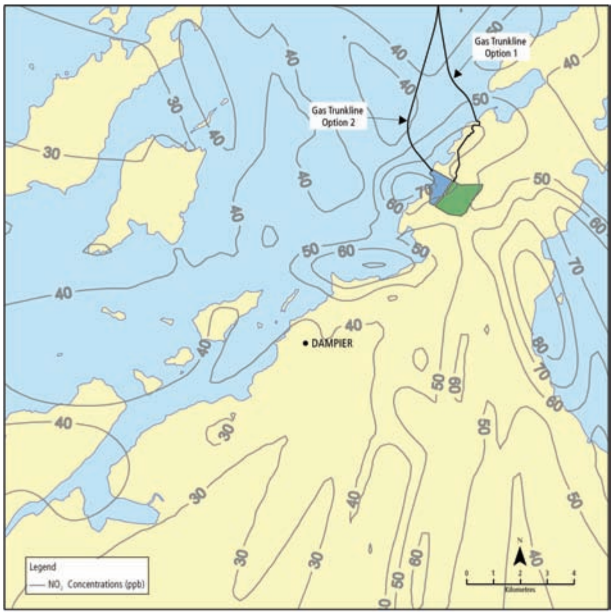
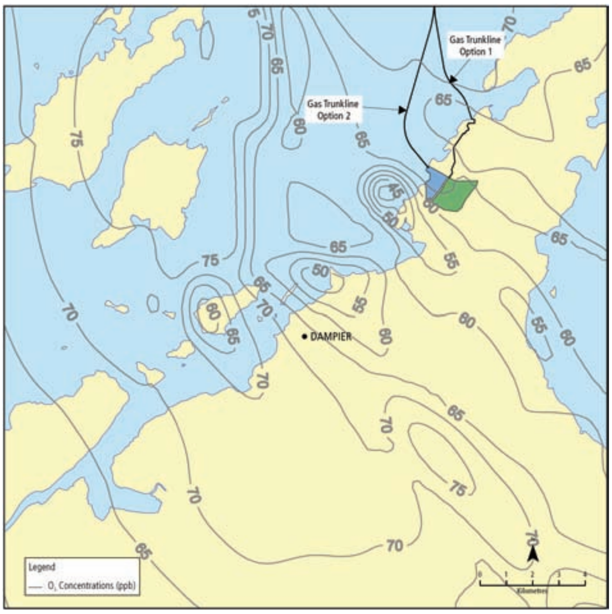


Figure 5-8 TAPM results for Maximum Hourly Average O_3 (ppb)



5.1.2.6 Discussion of the Key TAPM Results: NO_2 and O_3

The TAPM-predicted results for the key pollutants of NO_2 and O_3, indicate that there will be no exceedences of the NEPMs from the Pluto LNG Development during normal operations. For each of the non-routine, upset condition scenarios the TAPM modelling did identify an exceedance of the NEPM standard though these exceedances do not occur near residential areas or other sensitive receptors. As mentioned in **Section 5.1.2.3** the time of worst-case non-routine air emission scenarios cannot be known therefore air quality modelling was conducted assuming that non-routine emissions occurred over every hour of the year. This ensures that the modelling remains conservative and that the maximum ground level concentrations must be considered to be a worst-case prediction, as the low frequency of occurrence of the upset event, and the relatively short duration, mean that the emission and the conditions leading to the peak concentrations are unlikely to coincide. Examination of the second-highest concentrations across the model domain demonstrates that the standard is in fact exceeded for only one hour per year.

5.1.2.7 Deposition of Sulfur and Nitrogen on Sensitive Environments

The air quality assessment also included estimates for wet and dry depositions of SO_2 and NO_2. Although further scientific work is required to address uncertainties for modelling depositions, the Pluto LNG Development air quality assessment has provided results for these impacts.

The results of the TAPM modelling of depositions indicate that 'typical high' SO_2 and NO_2 depositions on the Burrup Peninsula are 1–2 kg/ha/annum (**Figure 5-9**), and 3–4 kg/ha/annum (**Figure 5-10**), respectively. The predicted deposition amounts on the Burrup Peninsula are well under World Health Organisation (WHO) standards for assessing the risks of impacts on vegetation. The ranges of WHO standards for various vegetation types have been used to provide some indication of the deposition amounts that may impact on vegetation in the Pilbara environment; these are 8–16 kg/ha/annum (SO_2) and 49–66 kg/ha/annum (NO_2).

5.1.2.8 Other Atmospheric Emissions and Pollutants

TAPM modelling was undertaken in 'tracer pollutant' (no photochemistry) for CO, BTEX, formaldehyde, acetaldehyde and PAH. The results for maximum 'tracer' pollutant concentrations on the computational grid were examined and none exceeded 1% of the assessment criteria. As such there is only a very low risk of impacts on ambient air quality from these pollutants.

Previous studies of BTEX at the Burrup Peninsula have found that ambient concentrations of BTEX are very low and not different from the ambient BTEX concentrations in many other parts of Australia. An assessment of the associated health risks concluded that they were, for practical purposes, zero (Drew 2005).

Figure 5-9 TAPM Predicted Annual SO_2 Deposition (kg/ha/annum)

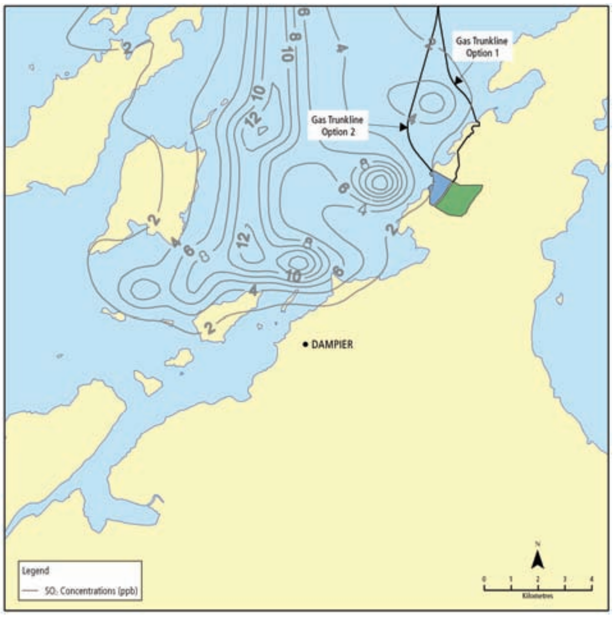
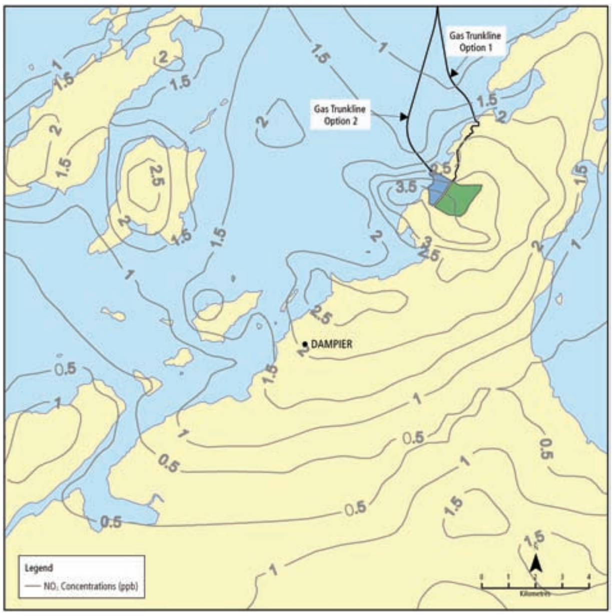


Figure 5-10 TAPM Predicted Annual NO_2 Deposition (kg/ha/annum)



5.1.2.9 Comparisons of Predicted Air Pollutant Concentrations with Standards and Guidelines

Comparisons of TAPM model-predicted air pollutant concentrations with Australian NEPM standards and WHO guidelines for deposition are provided in **Table 5-8**.

The NEPM provides an advisory reporting standard for $PM_{2.5}$ with the goal being to gather sufficient data (nationally) on these smaller particles to inform the review process for the NEPM, which was scheduled to commence in 2005.

5.1.3 Dark Smoke

Dark smoke is caused by the release of soot particles during flaring. Soot particles occur during incomplete combustion, when the flare is too cool or there is insufficient oxygen in the flame. The darkness of the smoke depends on the amount of carbon particles per volume of gas.

Under normal operating conditions, when the flare is operating efficiently, dark smoke is not produced. As such there is only a very low risk of impact on ambient air quality from dark smoke.

5.1.4 Dust

Dust emissions are likely to be confined largely to construction related activities, and are likely to vary substantially from day-to-day, depending on the level of activity, the specific operations and the prevailing meteorological conditions.

Emissions of dust as PM_{10} are expected from onshore construction activities. Specifically, during construction of the gas processing plant, dust emissions will be generated from the removal of topsoil, cut and fill activities, and wheel-generated dust.

Sensitive local receptors include the existing DPA and associated infrastructure to the south (2 km) and south-west (3 km) of Sites A and Site B respectively. The Karratha Gas Plant is also located 700 m to the north of Site A and Site B. The nearest residents live in Dampier, approximately 6 km in a straight line south-west of Site A and Site B. Other sensitive receptors include local vegetation, which can be smothered by dust particles resulting in reduced plant productivity.

The major sources of dust will be during site preparation works at Site B and during construction of the proposed trunkline corridor. Dust generating activities include:

- construction traffic transporting materials and the workforce to site
- drill and blast activities
- land clearing, earthworks, temporary stockpiling and backfilling
- the operation of a mobile crushing plant
- machinery operating along the gas trunkline construction corridor.

Table 5-8 Comparisons of Predictions with Standards and Guidelines

Air Pollutant	Averaging Period	NEPM Standard	Predicted Maximum Concentration for Pluto LNG Development/Associated Results
NO_2	1 hour Annual	120 ppb 30 ppb	89 ppb 9 ppb
O_3	1 hour 4 hours	100 ppb 80 ppb	79 ppb 67 ppb
Particles as PM_{10}	24 hours	50 µg/m³	Many exceedences due to iron ore handling.
Particles as $PM_{2.5}$	24 hours	25 µg/m³	Probable exceedences near Dampier due to iron ore handling (assuming $PM_{2.5}$ ~ 20% of PM_{10} on windy days)
	Annual	8 µg/m³ (advisory–gather data)	Probable exceedences near Dampier (iron ore handling).
SO_2	1 hour Annual	200 ppb 20 ppb	110 ppb 6 ppb
SO_2 (deposition)	Annual	WHO (2000): 8-16 kg/ha/annum	Typical high 2 kg/ha/annum
NO_2 (deposition)	Annual	WHO (2000): 49-66 kg/ha/annum	Typical high 4 kg/ha/annum
All other pollutants (CO, VOCs, etc.)	Various	Various	All significantly less than EPA goals; for example, Victorian EPA, NSW DEC.

5.1.5 Odour

Potential sources of odour associated with the Pluto LNG Development are likely to be limited given that gas including LNG does not naturally have an odour. The sulfur content of the Pluto reservoir fluids is very low, such that sulfur emissions from combustion processes are expected to comprise approximately 0.875 mg/m³ (as SO_2). Due to these low sulfur levels, odour emissions of sulfurous compounds (for example, as H_2S) are not expected to be significant. In addition, there is no known history of odour complaints from the existing NWSV Karratha Gas Plant. Odour emissions are therefore not anticipated.

5.1.6 Light

The generation of artificial light from construction and operation of the Pluto LNG Development has the potential to result in light spill, particularly during night-time operations. There are a number of existing light sources on the Burrup Peninsula and in the vicinity of the proposed Pluto LNG Development including the existing NWSV Karratha Gas Plant located to the north of Site A and Site B and the DPA to the south of Site A.

The amount of light spill generated from the nearshore and offshore facilities during construction and operation will be determined by the wavelength and intensity of the light source, the location and/or placement of light fittings and the method of light switching. Light intensity, similar to noise, will attenuate with distance.

Construction lighting typically consists of bright white (metal halide, halogen, florescent) lights. These lights will be used offshore during the construction phase on a 24-hour basis. Vessels operating within the Dampier Archipelago during dredging of the navigation channel, associated spoil disposal and installation of the gas trunkline in nearshore waters will require 24-hour lighting. The dredging associated with construction of the navigation channel, turning basin, berthing pocket and trunkline is anticipated to take up to 24 months (refer to **Section 4**). Temporary lighting will also be provided during construction of the gas trunkline landfall at either the Karratha Gas Plant (gas trunkline Option 1), or Site A, Holden Point (gas trunkline Option 2).

During operations, the export jetty and the offshore platform will be lit continuously, and the supply vessels will also emit light. Flaring may occur during blow down events and during start up activities at the offshore platform location. Artificial lighting is likely to also be used 24-hour basis during the operation of the gas processing plant at Site B and at Site A. Elevated structures are likely to be lit for aviation safety, and boundary fence lighting may also be provided.

5.1.7 Noise

5.1.7.1 Marine Noise

Marine noise will be generated during construction and operation of the Pluto LNG Development from various activities, vessels and fixed structures. Principal marine noise sources are presented in **Table 5-9** and associated impacts assessed in **Section 7.11**.

It must be noted that noise is propagated and measured differently in water than on land. The standard scientific approach is to describe underwater noise levels in terms of sound pressure. While a decibel (dB) is a relative measure of sound level, in order to make this measure meaningful for underwater noise, it is referenced to a standard 'reference intensity' of 1 mPa (dB re 1μPa). Underwater noise is also measured over a specified frequency, usually either a 1 Hz bandwidth (expressed as dB re 1μPa^2/Hz), or over a broadband that has not been filtered. Where the frequency has not been expressed, it is assumed that the measurement is a broadband measurement.

Naturally occurring noise levels in the ocean as a result of wind and wave action may range from around 90 dB re 1μPa under very calm, low wind conditions to 110 dB re 1μPa under windy conditions.

A summary of comparable average noise levels expected from marine construction and operation activities are presented in **Table 5-10**. The levels range from 154 dB re 1μPa at 1 m to 198 dB re 1μPa at 1 m.

Drilling

The noise emitted from Mobile Offshore Drilling Units (MODU) consists of a combination of drill pipe operation and onboard machinery, and typically produces low intensity but continuous sound. Semi-submersible vessels are generally less noisy than drill ships (Richardson et al. 1995) as they lack large hull areas and the machinery is mounted on decks raised above the sea on risers supported by submerged flotation chambers. In contrast, the drill ship hull contains the rig, the generators and other machinery and is well coupled to the water. Most noise is likely to be in the 10 to 500 Hz frequency range.

A range of broadband values (59 to 185 dB re 1μPa) have been quoted for various drill ships and jackup drilling rigs (Simmonds et al. 2004). Noise is likely to be between 100 to 160 dB re 1μPa in intensity while drilling, and between 85 to 135 dB re 1μPa when drilling is not occurring, based on observed levels from a range of programs

In the Otway Basin, Woodside (2002) measured ocean noise at a distance of approximately 5.1 km from a semi-submersible MODU over a period of 32 days. Drilling noise was dominated by sharp tones (<100 Hz) with little high frequency noise. The maximum broadband noise level recorded was 145 dB re 1μPa and noise levels exceeded thresholds of 100 dB re 1μPa and 120 dB re 1μPa, 70.5% and 0.7% of the time respectively across the duration of drilling operations (Woodside 2002).

In the Timor Sea, McCauley (1998) measured noise emitted from a semi-submersible drilling rig at approximately 146 dB re 1μPa when not actively drilling and 169 dB re 1μPa when drilling. The maximum audible range for a MODU was 11 km under ideal conditions while drilling and only 1 to 2 km while not drilling (McCauley 1998).

Table 5-9 Key Noise Sources From Construction and Operation Activities

Construction and Commissioning Sources	Operation and Decommissioning Sources
Semi-submersible drill rig	Wellheads, flowlines and trunkline
Trunkline installation vessels	Riser platform topsides
Dredging vessels: trailer suction hopper dredge, cutter suction dredge and backhoe dredge	Platform support and supply vessels
Platform installation vessels	LNG and condensate tankers
Subsea infrastructure installation vessels	Field and gas trunkline inspection vessels
Helicopter operations	Helicopter operations
Pile hammering	Decommissioning vessels

Table 5-10 Predicted Noise Levels from Marine Activities

Source	Source Level of Dominant Tone	
	Freq. (Hz)	dB re 1μPa at 1 m
Drilling - Mobile offshore drilling unit	N/A	100 – 160 during drilling 85 – 135 when not drilling
Dredging - Cutter suction dredges and hopper dredges	N/A	135–150
Support Vessels	N/A	130 – 182
Tankers	10 – 400	169 – 198
Helicopters	22	149–151

Dredges

Noise from cutter suction dredges and trailer suction hopper dredges has been recorded ranging from 135 dB re 1μPa to 150 dB re 1μPa at distances of less than 0.2 km (Greene 1985: 1987).

LNG Tankers

Every vessel has a unique signature, which changes with ship speed, the condition of the vessel, vessel load and the activities taking place on the vessel. Modelled data for tankers of a size comparable to LNG tankers indicates that noise levels would vary between approximately 135 to 180 dB re 1μPa depending on vessel load and speed (OSB 2003).

Support Vessels

Support vessels include vessels used temporarily during drilling and installation, and those that will be routinely used during operations, such as the offloading support vessel and supply vessels.

The noise characteristics and level of various vessels that will be present in the field over time will vary considerably between vessel types. The particular activity being conducted by the vessel also greatly influences the noise characteristics, for example, if it is at idle, holding position using bow thrusters, or accelerating.

Vessel propellers are primarily designed to drive the vessel at a steady cruising speed. They are less efficient and noisier in reverse, or when accelerating hard. While working, support vessels normally maintain position during loading and unloading supplies, or conducting installation activities, using strong forward and reverse thrusts from the engines and bow thrusters. This type of activity would only take place for a very small proportion of the time.

McCauley (1998) measured underwater broadband noise equivalent to approximately 182 dB re 1μPa at 1 m from a MODU support vessel holding station in the Timor Sea. This level of noise compares to reported levels of 170 dB re 1μPa measured from whale watching catamarans in Hervey Bay, Queensland, during manoeuvring (McCauley et al. 1996) and 168 dB re 1μPa measured from a 20 m fishing boat in the Timor Sea (McCauley 1998).

Helicopter Operations

Helicopter noise generation at the source ranges from 149–151 dB re 1μPa at 1 m, but the penetration of the noise into the ocean is dependent on the angle of the aircraft and its distance from the sea surface. At angles greater than 13° from the vertical, most of the sound does not penetrate into the water and is instead reflected. This correlates highly with calm seas, deep water or shallow waters with a non-reflective bottom, but some sounds may penetrate in rough seas as they provide sea surfaces at suitable angles (Richardson et al. 1995).

Table 5-11 illustrates that the altitude of the helicopter above the sea surface alters the noise emissions received in the marine environment. The closer the aircraft is to the sea surface the higher the level of noise generation received, and vice versa.

Table 5-11 Estimated Source Levels for Helicopter Noise

Aircraft (frequency)	Aircraft Altitude (m)	Received Level (dB re 1μPa)	Estimated Source Level (dB re 1μPa at 1 m)
Bell 212 (22 Hz Tone)	152	109	149
	305	107	151
	610	101	151

Source: Adapted from Richardson et al. 1995

Offshore Platform and Facilities

Given that the offshore platform is elevated above sea level, very little noise energy would be transmitted underwater. The more likely sources of underwater noise from fixed facilities are the wellhead, flowlines and trunkline.

The noise produced by an operational wellhead was measured by McCauley (2002). The broadband noise level was very low, 113 dB re 1 μPa, which is only marginally above rough sea condition ambient noise. For a number of nearby wellheads the sources would have to be in very close proximity (< 50 m apart) before their signals summed to increase the total noise field (with two adjacent sources only increasing the total noise field by 3 dB). Hence for multiple wellheads in an area, the broadband noise level in the vicinity of the wellheads would be expected to be of the order of 113 dB re 1 μPa and this would drop very quickly to ambient conditions on moving away from the wellhead, falling to background levels within a few hundred metres from the wellhead.

There are no substantial flow restrictions in the gas trunkline, thus the primary mechanism for generating sound within the trunkline (turbulent flow around an obstruction) will be minimised. This implies that the source levels of sound within the trunkline will be low. The trunkline will also have an external concrete coating that will act to dampen the transfer of sound from within the pipe to the water column. It is therefore unlikely that there will be any significant sound produced along the trunkline length. It is probable, that under moderate sea states, any trunkline noise will be completely lost among the background sea noise at ranges greater than approximately 50 m from the trunkline.

5.1.7.2 Terrestrial Noise

An assessment of noise associated with onshore facilities has been undertaken by SVT Engineering Consultants (SKM 2006b). This section outlines the noise sensitive receptors in the vicinity of the development area and describes construction and operation noise sources.

Human receptors are discussed in **Section 10** and summarised in **Table 5-12**.

Table 5-12 Approximate Distances of Sensitive Receptors in Relation to the Pluto LNG Development

Receptor	Location	Distance from Site A (km)	Distance from Site B (km)
Residential Properties	Dampier Township	6	7
	Karratha Township	17	15
Recreational Facilities and Beaches	Hearson Cove	4	3
	Beach at Site A	<1	<1
Business and Industrial Properties	Mermaid Marine Facility/ Woodside Supply Base	2	2
	Dampier Port/ Western Stevedores	<1	1
	Karratha Gas Plant	<1	2
	Burrup Fertiliser Ammonia Plant	2	2
Road network	Burrup Road	1	<1
	Village Road	1	<1

Background Noise Levels

Background noise monitoring has been undertaken at off-site receptors including Hearson Cove, Dampier and Village Road as well as at Site A. The monitoring period was from 5 December 2005 to 20 December 2005. Results are presented in **Table 5-13**.

The results of background noise monitoring identify some non-typical trends, for example, at Hearson Cove it would be expected that day time noise levels would be highest, however, the results indicate noise levels increase after noon, and reach a peak during the evening between approximately 6–10 pm. It is likely that the measured increase in noise level during the afternoon and evening periods is due to recreational users on the beach and that in the absence of this activity background levels are very low.

The ambient noise results for Village Road indicate that levels are dominated by activities at the Burrup Fertilisers Ammonia Plant. At Site A, ambient noise levels are consistent for day and evening periods. Noise levels at Dampier are influenced by local traffic and activities at Pilbara Iron's Dampier port operations.

Table 5-13 Ambient Noise Levels at both On and Off-Site Locations

Location	L90* of LA90 Noise Levels period		
	Day (nominally 7 am – 7 pm)	Evening (nominally 7 pm – 10 pm)	Night (nominally 10 pm – 7 am)
Hearson Cove	24	32.5	29
Village Road	45.5	52.5	50
Site A	34	34.5	33
Dampier	37	41	34

Note: LA90 is the level of noise exceeded for 90% of the time based on noise level monitoring at 15 minute intervals. The 90th percentile of these readings (the L90 of LA90 values) are extracted to determine the underlying background noise level, i.e the LA90 level that is exceeded for 90% of the total monitoring period.

Table 5-14 presents typical sound pressure levels to allow comparisons between background noise levels and predicted noise levels during construction and operation phases of the Development.

Table 5-14 Typical Sound Pressure Levels for Comparison Purposes

Sound Pressure Level (dB)	Typical Environment	Average Subjective Description
140	30 m from jet aircraft	Intolerable
130	Pneumatic chipping and riveting (operator's position)	
120	Boiler shop (maximum levels)	
110	Chainsaw	Very noisy
100	Disco	
90	Heavy lorries at 6 m	
80	Kerbside of busy road	Noisy
70	Loud radio	
60	Restaurant	
50	Conversational speech at 1 m	Quiet
40	Residential area at night	
30	Quiet bedroom at night	
20	Background in TV and recording studios	Very quiet
10		
0	Threshold of hearing	

Source: Alcan 2004

Construction and Commissioning Noise

A range of activities will be undertaken during construction that will generate noise emissions. Construction activities associated with the gas processing plant and storage and export facilities are described in **Section 4** and can be summarised as follows:

- construction traffic
- earthworks
- the creation of temporary laydown areas
- piling
- concrete batch plant
- the laying of site drainage and internal roads
- the installation of gas processing plant
- hydrotesting of storage tanks.

Construction traffic includes buses, utilities, large flat bed loaders (transporting pre-assembled units) and heavy machinery. Earthworks involve various activities such as clearing and levelling the construction site, cut and fill activities and rock supply. Piling is undertaken to create suitable foundations for the gas processing plant and storage and export facilities.

Construction and commissioning activities associated with the gas trunkline include:

- clearing and grading
- blasting (if required)
- trenching, stringing, bending and lowering
- welding joint coating
- hydrotesting
- padding, shading and backfilling.

All construction work will be carried out in accordance with the Environmental Protection Noise Regulations 1997 (WA) and AS 2436-1981 Guide to Noise Control on Construction, Maintenance and Demolition Sites.

Operation Noise

During operations, the majority of noise is likely to be emitted from the gas processing plant at Site B. The key noise sound power sources will include:

- compressors (multiple) – up to 123 dB(A)
- air-fin coolers (multiple) – up to 118 dB(A)
- piping – up to 120 dB(A)
- power generators (multiple) – up to 105 dB(A)
- other items – up to 113 dB(A).

At Site A, other than the noise generated during vessel loading operations, the key noise source will be from the boil-off gas compressor with associated noise emissions of up to 114 dB(A). The Pluto LNG Development could also potentially cater for Domgas. Based on previous measurements recorded at the NWSV Karratha Gas Plant, noise emissions associated with compressor suction, discharge and recycling piping, are likely to be up to 125 dB(A).

Noise Limits

Noise management in Western Australia is implemented through the Environmental Protection (Noise) Regulations 1997 which operate under the EP Act. The Regulations specify maximum noise levels (assigned levels) which are the highest noise levels that can be received at noise-sensitive, commercial and industrial premises. For noise sensitive premises, such as residences, an 'influencing factor' is incorporated into the assigned noise levels. The influencing factor depends on land use zonings within circles of 100 m and 450 m radius from the noise receiver, including:

- the proportion of industrial land use zonings
- the proportion of commercial zonings
- the presence of major roads.

For noise sensitive residences, the time of day also affects the assigned levels. The regulations define three types of assigned noise levels:

- L_{Amax} assigned noise level means a noise level which is not to be exceeded at any time
- L_{A1} assigned noise level which is not to be exceeded for more than 1% of the time
- L_{A10} assigned noise level which is not to be exceeded for more than 10% of the time.

The L_{A10} noise limit is the most significant during the operation phase since this is representative of continuous noise emissions from the proposed Development. The L_{A10} assigned noise level for the southern plant boundary of Site B is 65 dB(A) at all times of the day since receiving premises at this boundary are zoned for industrial use.

The assigned noise levels at residential premises in Dampier will vary depending on the proximity of particular premises to industrial and commercial areas and also the time of day. The most stringent night-time L_{A10} assigned noise level at residential premises in Dampier is 35 dB(A) for those residences that are greater than 450 m from land zoned for industrial or commercial use. This limit has been used for the purposes of this assessment.

The design of the gas processing plant is not sufficiently advanced to determine whether there will be any intrusive or dominant characteristics in noise emissions (that is, whether the noise will be compulsive, tonal or modulated). However, since potentially there are many noise sources with similar noise emission levels, it is unlikely that any single source will have a dominating influence on the characteristics of the noise received at locations beyond the site boundaries.

The Environmental Protection (Noise) Regulations 1997 do not address noise received at Hearson Cove, which is not classified as premises. However, EPA bulletin 1077, November 2002, relating to the proposed Methanol Complex at Site E on the Burrup Peninsula, describes an aspirational noise goal of 45 dB(A) under westerly wind conditions for Hearson Cove:

> The principle of "all reasonable and practicable measures" under the *Environmental Protection Act 1986* requires proponents to get impacts down as low as reasonably practicable within the definition of the Act. A cumulative level of 45 dB(A) at the beach is recommended by the EPA as an aspirational goal to help maintain the amenity at Hearson Cove. While this aspirational goal is not mandatory, it provides some guidance on a target for all proponents to strive to achieve.

This goal applies at the southern beach shelter at Hearson Cove.

Modelling Approach

An acoustic model has been developed using the Environmental Noise Model (ENM) programme, originally developed by RTA Technology for the Australian Noise Advisory Council. The ENM programme calculates sound pressure levels at nominated receiver locations or produces noise contours over a defined area of interest around noise sources. The inputs required are noise source data, ground topographical data, meteorological data and receiver locations.

The model has been used to generate noise contours for the area surrounding the proposed development and also to predict noise levels at the site boundary and at noise sensitive locations in the vicinity of the gas processing plant. The model does not include noise emissions from any sources other than the proposed development. Noise emissions from road traffic, rail, aircraft and domestic sources are therefore not accounted for.

Noise Modelling Results

Table 5-15 presents the noise levels predicted at the southern site boundary (Site B), Hearson Cove and Dampier. Noise contours for 3 m/s westerly and northerly winds combined with a 2°C/100 m thermal inversion are presented in **Figure 5-11** and **Figure 5-12**.

At all locations, the following noise sources dominate received noise levels:

- compressor suction, discharge and recycle piping
- air coolers.

Table 5-15 Predicted Noise Levels

Weather Conditions			Predicted Noise Levels - dB(A)		
Wind Direction	Wind Speed	Inversion	Site B Southern Boundary	Hearson Cove	Dampier
Calm	Calm	No	65	36	25
N	3 m/s	No	67	39	30
S	3 m/s	No	63	31	21
E	3 m/s	No	67	29	30
W	3 m/s	No	64	40	21
Calm	Calm	Yes	66	39	29
N	3 m/s	Yes	69	40	31
S	3 m/s	Yes	64	34	22
E	3 m/s	Yes	68	31	31
W	3 m/s	Yes	65	42	22

Figure 5-11 Noise Contours for 3 m/s Westerly Wind with 2°C/100 m Thermal Inversion

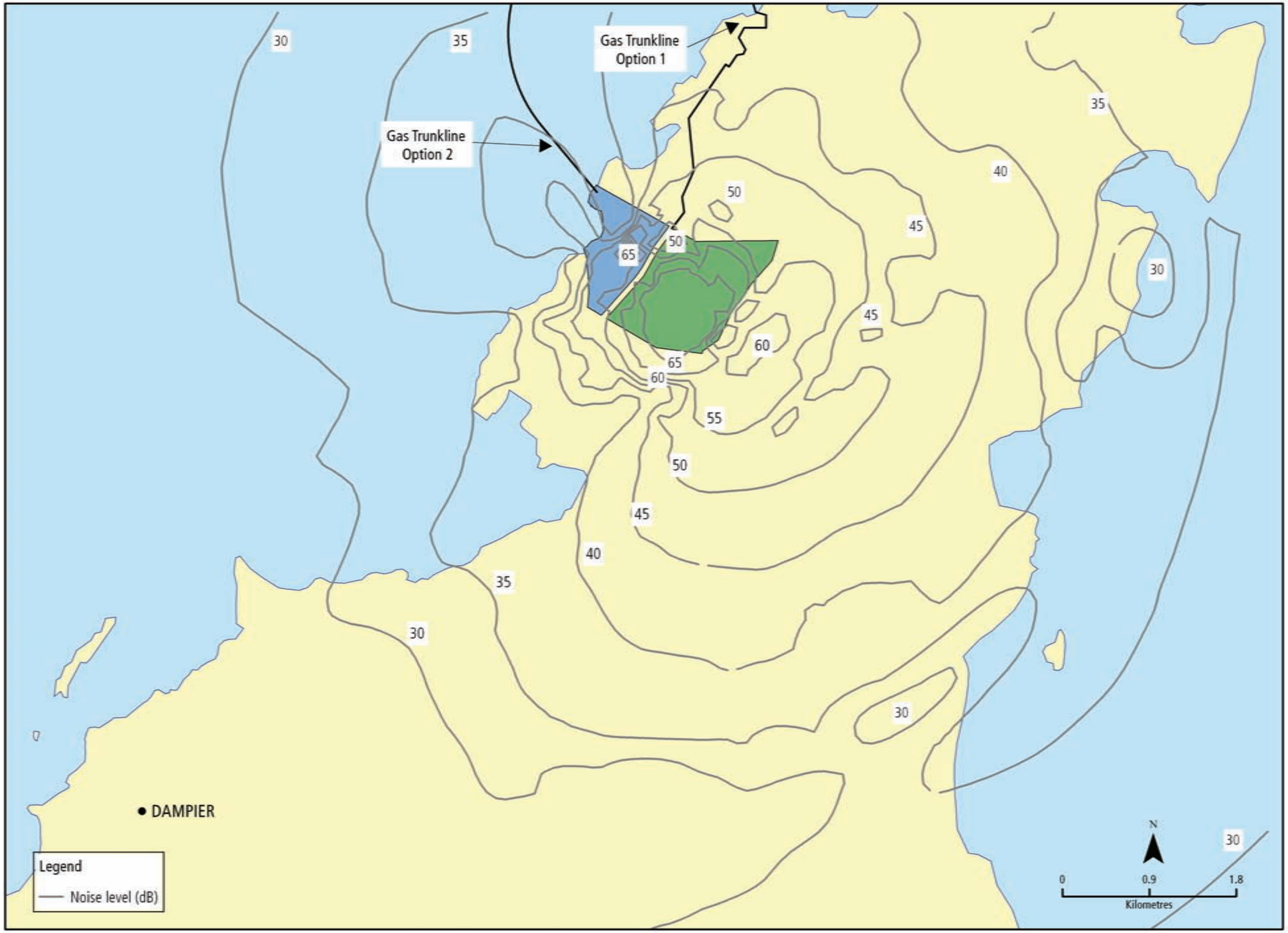
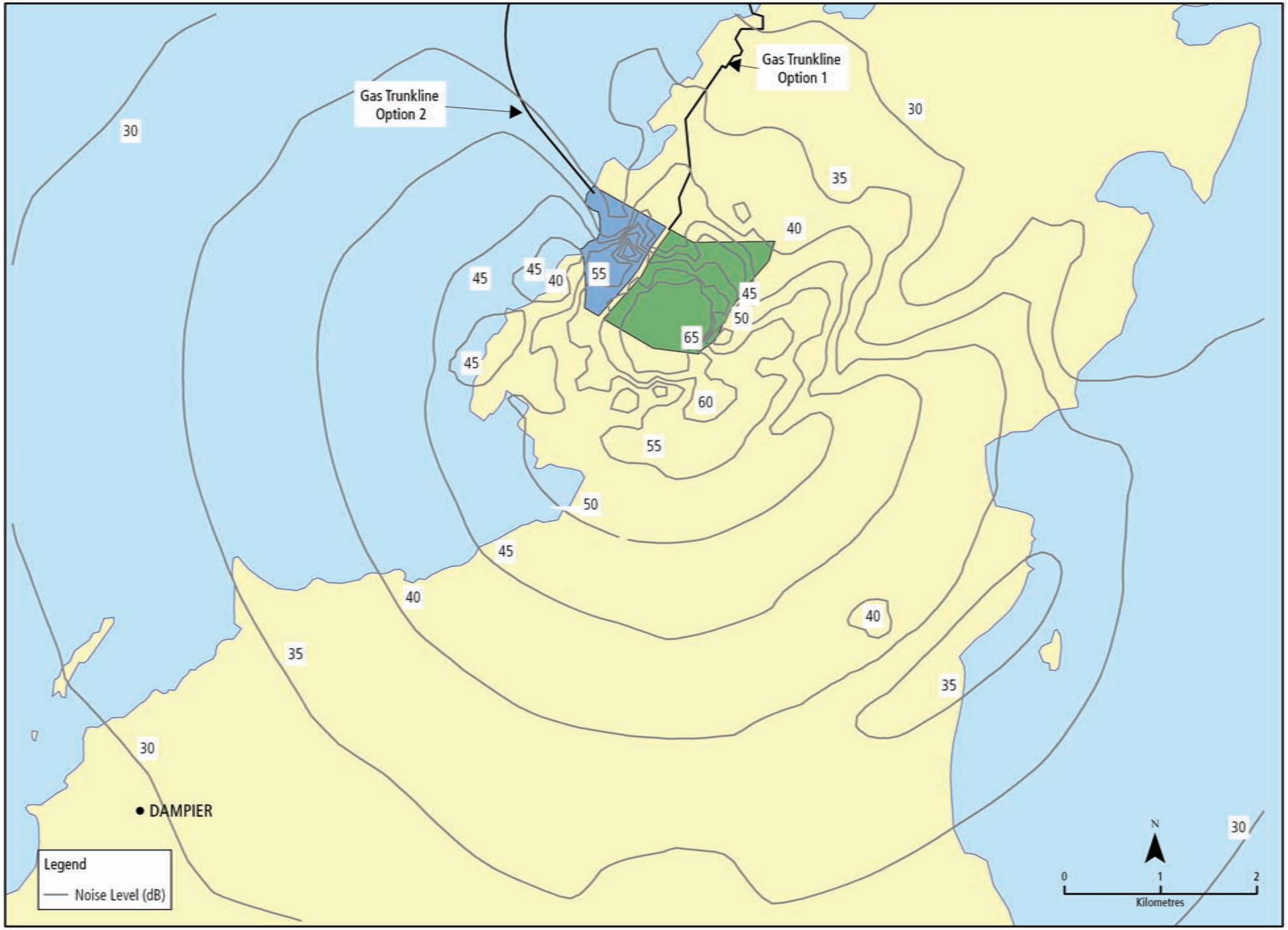


Figure 5-12 Noise Contours for 3 m/s Northerly Wind with 2°C/100 m Thermal Inversion



5.2 Marine Discharges and Waste

5.2.1 Overview

This section discusses waste streams that are likely to be disposed of into the offshore and nearshore marine environment. The key marine discharges are summarised below and also in **Table 5-16**. They include:

- surface discharges of drill cuttings and drill fluids
- disposal of spoil from trunkline trenching and dredging operations associated with construction of a navigation channel, berthing pocket and turning basin
- discharge of treated waste water streams comprising produced water, sewage and grey water, non routine contaminated water and AOC water from the gas processing plant.

To determine the degree of environmental impact resulting from discharges to the marine environment, numerical modelling studies have been undertaken for dredge spoil disposal and treated waste water. The findings from these studies and the associated potential impacts are discussed in **Section 7**.

5.2.2 Drill Cuttings

During the drilling of individual wells, the drill bit grinds the rock forming drill cuttings, which subsequently become entrained in the mud flow used to control subsurface pressures and to lubricate the drill bit. Some of these cuttings are discharged directly onto the seabed in instances where the top sections of the well are drilled without a riser. For deeper sections of the well drilled with NWBM, a riser will be used and will return cuttings to the drill rig at the surface, where the cuttings will be separated from the drill muds over vibrating screens, commonly referred to as 'shale shakers'. Depending on the effectiveness of the initial screening, the cuttings may require further treatment to reduce the amount of base fluid adhering to the cuttings, prior to overboard discharge. The management of drill cuttings is further discussed in **Section 7**.

The character of the cuttings to be discharged overboard can be predicted using lithological data from the appraisal and exploration wells. Retrieved cuttings can be expected to range in size from very fine to very coarse (<10 mm) particle and sediment.

Estimated drill cutting volumes for each well are given in **Table 5-17**, together with the type of drill mud likely to be used (**Section 5.2.3**). A total of approximately 568 m^3 of drill cuttings is likely to be generated for each well drilled.

Table 5-16 Summary of Key Marine Discharges and Waste

Marine Discharge/ Waste	Discharge Location	Construction Phase (3–4 years)	Commission Phase (<1 year)	Operational Phase (30 years)	Decommissioning Phase
Drill Cuttings	Offshore	✓		✓	
Drilling Fluids/ Muds	Offshore	✓		✓	✓
Sludges and Sands	Offshore	✓		✓	✓
Well Completion Fluids	Offshore		✓	✓	✓
Subsea Control Fluids	Offshore		✓	✓	✓
Cooling Water	Offshore	✓	✓	✓	✓
Hydrate/ corrosion Inhibitors (MEG)	Nearshore	✓	✓	✓	
Dredge Spoil	Off/ Nearshore	✓	✓	✓*	
Deck Drainage	Off/ Nearshore	✓	✓	✓	✓
Hydrotest Fluids	Offshore		✓	✓	
Produced Water	Off/ Nearshore		✓	✓	
Anti-Fouling	Off/ Nearshore	✓	✓	✓	✓
Ballast Water	Off/ Nearshore	✓	✓	✓	✓
Sewage and Grey Water	Off/ Nearshore	✓	✓	✓	✓
Food scraps	Off/ Nearshore	✓	✓	✓	✓
Non routine and AOC water	Nearshore	✓	✓	✓	✓
Demineralised Water	Nearshore		✓	✓	

** The requirements for future maintenance dredging cannot be determined at this stage and is not considered further in this Draft PER.*

Table 5-17 Preliminary Estimation of Drill Cuttings Volumes per Well Drilled

Hole Section Diameter (mm)	Estimated Cuttings Volume (m^3)*	Mud Type	Discharge Location
914 (36")	13	WBM (and gel system)	Seabed
660 (26")	223	WBM (and gel system)	Seabed
444 (17 ½")	204	Gel system	Surface
311 (12 ¼")	95	NWBM	Surface
216 (8 ½")	33	NWBM	Surface
Total	568		

** Calculated in-situ volume*

The piling required for platform legs will also result in cuttings being removed from the pile holes. Assuming a maximum of 16 pile holes, each of which are 3 m in diameter and up to 60 m deep, the maximum amount of cuttings from pilings for the riser platform legs will be in the order of 27 000 m^3. The cuttings from pilings would be discharged at the seabed. Assuming that there is no or minimal dispersion, this equates to cuttings piles approximately 20 m in radius, reaching a height of approximately 4 m at the base of each platform leg.

5.2.3 Drilling Fluids and Muds

Drilling mud is formulated according to the well design, the expected reservoir geological conditions and the surrounding formations. Drill mud comprises a base fluid, weighting agents and chemical additives used to give the mud the exact properties required to make the drilling as efficient and safe as possible. Drill mud serves a number of functions including:

- the removal of drilled solids (that is, cuttings) from the bottom of the hole and their transport to the surface, where they are separated from the mud (the mud is recycled back to the well bore)
- deposition of an impermeable cake on the well bore wall to seal the formations being drilled
- preventing contaminants entering the mud and/or the fluid entering the formation
- suspension of drill cuttings in the mud during interruption of drilling
- maintaining the structural stability of the well bore
- maintaining annular pressure control
- delivering hydraulic energy
- providing a suitable medium for wire line logging
- lubricating and cooling the drill bit.

Drilling muds are likely to comprise a combination of WBM and NWBMs, the latter being either a low toxicity ester based mud or synthetic based mud. A variety of additives are commonly used in mud systems including polymer, caustic soda, barite and starches.

Water based muds will be used as a preference. However, where this is not technically feasible, for example where they cannot provide the required lubrication, borehole stability or other properties, a NWBM will be used.

As a well is drilled, the muds are returned to the surface and are adhered to the drill cuttings. The drilling muds are then separated from the drill cuttings and re-circulated down the well. However, not all of the drill muds can be separated from the cuttings and some muds will inevitably be discharged overboard with the drill cuttings. The toxicity effects of contaminated drill cuttings on marine biota are well understood (**Section 7.8.1**). NWBMs are widely used in drilling programmes in Western Australia.

The drilling muds will be securely stored onboard the drill rig. The fluids will be mixed and continually added to the drilling process to replenish the fluids lost with the cuttings overboard. Following the completion of drilling, WBMs will be discharged to sea while NWBMs will be recovered and returned to the supplier onshore for reuse or disposal.

5.2.4 Sludges and Sand

On the basis of core samples taken during appraisal drilling, it is anticipated that sands will be produced during drilling, and that active sand control measures will be necessary. Sludges and sands suspended in drill mud and returned to the drilling rig may contain hydrocarbons and will require treatment, prior to over-board disposal.

5.2.5 Well Completion Fluids

Well completion fluids will be used once a well has been drilled, to ensure that the surface is clean and also to prevent blockage within the reservoir. This may involve installing a suitable well casing, cementing the casing and perforating the lower section to access the gas producing horizons. However, an alternative sand-face completion may be installed (such as gravel-pack or expandable sand screens).

The type of completion fluid used will depend on the type of drilling fluids selected. In instances where a WBM is used, the completions fluid is likely to be brine. Should NWBMs be used, the NWBM will be displaced from the well and replaced with brine prior to installing the completion. To allow the well to flow, a low weight fluid (such as diesel) may be displaced into the completion string to provide the necessary 'under-balance'. The management of well completion fluids is discussed in **Section 7.8.4**.

5.2.6 Subsea Control Fluids

A water-based subsea control fluid will be used to control wellhead valves remotely from the riser platform. It is likely that this will operate on an open-loop system with small amounts of control fluid discharged from the wellhead valves on the seabed when they are operated. Operation of the control valves typically results in a discharge of 6 – 20 l of subsea control fluid with an estimated total volume of 30 m^3 being discharged at the Pluto gas field location per year. The open-loop control systems are the industry standard. The majority of fresh-water based fluids contain additives of MEG, lubricants, corrosion inhibitors, biocides and surfactants. Potential impacts associated with subsea control fluids are discussed in **Section 7.8.4**.

5.2.7 Cooling Water

The treatment of reservoir fluids offshore on the platform may require cooling water upon entry to the platform separation unit. A seawater intake pipe would extract seawater and discharge it back to the marine environment at 60°C. The volume of cooling water will be confirmed during front end engineering and design, although it is anticipated it will be relatively minor. The potential impacts and management of cooling water are discussed further in **Section 7.8.12**.

5.2.8 Hydrate/Corrosion Inhibitors

Corrosion and hydrate inhibitors such as MEG will most likely be used in the offshore flowlines and gas trunkline. Subsea wells will be tied back to the riser platform. There will be need for continuous MEG injection for hydrate/corrosion control into the flowlines. The MEG (including dissolved corrosion inhibitor) will be sent to shore and be separated from the produced water in a MEG regeneration facility. Most of the residual MEG contained within the water from the MEG regeneration facility will be removed from the water by the water treatment facilities prior to discharge. Trace quantities of MEG will be treated to <50 mg/L and combined with the treated waste water stream and discharged via a marine discharge pipeline at the end of the jetty into Mermaid Sound (**Section 5.2.15**).

5.2.9 Dredge Spoil

Dredging will be required for the construction of the navigation channel, turning basin and jetty and for the installation of the gas trunkline in nearshore waters (**Section 4**). Dredge spoil generated from these construction-related activities will be disposed of at a combination of the existing spoil ground A/B located within Mermaid Sound, a northerly extension to this ground and a deepwater location north of Mermaid Sound (**Figure 4-15**). Additionally there is potential for some spoil to be re-used as backfill in the trunkline trench.

For the offshore sections of the trunkline route, spoil will be disposed of approximately 1–2 km from the trunkline route out to a depth of up to 50 m CD. All proposed spoil disposal locations are identified in **Section 7.9**.

Spoil generated from the construction of the inshore sections of either gas trunkline Option 1 or gas trunkline Option 2, within the DPA limits will be disposed of at the proposed deep water spoil ground site 2B to the north of the Dampier Archipelago. All spoil generated from the trunkline installation beyond DPA limits will be disposed into deep water spoil ground 5A.

Sampling of the sediment to be dredged was conducted over the proposed dredging areas within DPA limits. The results indicate that the concentration of potential contaminants are below the screening levels listed in the National Ocean Disposal Guidelines for Dredged Material (NODGDM), and the sediments are therefore considered suitable for disposal at sea. The results of the surveys are discussed further in **Section 6.2.4**.

The levels of potential contaminants in spoil generated from dredging outside DPA limits is unlikely to be above the levels found in nearshore sediments given the remoteness of the location to shipping activity, existing industry and other known pollution sources. Furthermore, material comprised largely of sand, gravel and rock may be considered clean of contamination for spoil disposal purposes (Environment Australia 2002). Preliminary analysis of geophysical data from the offshore seabed along the offshore trunkline route indicates that surface sediments comprise of carbonate sand and shell grit overlaying calcarenite. Layers of unconsolidated sediments decrease to thin veneers with distance offshore. The sand component of the unconsolidated sediments range from fine to coarse with shell gravel and shell fragments (Woodside 2005d), and is considered to fall within the category of sediments considered clean and suitable for ocean disposal.

5.2.10 Deck Drainage

Deck drainage water systems are likely to comprise both uncontaminated, clean water and contaminated water and will be segregated and contained to prevent direct discharge to ocean. Clean rainwater will generally be directed overboard without treatment. Contaminated and potentially contaminated deck drainage, for example from the drill rig, support vessels, pipelay barge and dredging vessels, and operating vessels and structures (riser platform, support and supply vessels, export tankers) will likely contain some oils, greases and other contaminants. The management of deck drainage water is discussed further in **Section 7.8.5**.

5.2.11 Hydrotest Fluids

Hydrostatic pressure testing will be necessary during pre-commissioning to ensure integrity of the offshore flowlines, gas trunkline, onshore LNG tanks and other storage vessels, piping and onshore pipelines between Site A and Site B.

Preliminary estimates, based on a 1068 mm (42") gas trunkline diameter indicate that up to 153 000m^3 hydrotest water may be generated for the trunkline. Pressure testing of the MEG supply line from the onshore gas processing plant to the riser platform would require an estimated 30 000 m^3 of hydrotest water. Hydrotest water will consist of chemically treated seawater and will be introduced at the offshore end of the trunkline. The trunkline will be filled and emptied from the offshore end with seawater containing chemicals, likely to comprise biocides, corrosion inhibitor and oxygen scavenger (for example, ammonium bisulphite) to prevent internal pipe corrosion and bacterial formations and scale inhibitor to prevent build up of scale. Fluorescein dye may also be added to enable the easy identification of leaks.

It is anticipated that the gas trunkline, flowlines and MEG supply line will be hydrotested separately. Following pressure testing, a pig train will be used to drive water out of each pipeline and hydrotest water will be disposed of at the offshore end. Pig trains are likely to include one or two slugs of MEG to aid pipe dehydration and condition the line, in accordance with standard industry practice. The MEG included in the pig trains will also be discharged to sea along with the hydrotest water.

The only exception to this philosophy will be for hydrotesting and pre-commissioning of the MEG service line from the riser platform to the well manifold. This section of the MEG supply line is expected to be filled directly with MEG, rather then treated with seawater. Hydrotesting of this line would be then undertaken using MEG and, after depressurisation, will be ready for operation.

The LNG and condensate storage tanks will require up to 160 000 m^3 of hydrotest water. It is also assumed that hydrotest water will be re-used between tanks to allow hydrotest completion of the other tanks. Hydrotesting of LNG tanks and onshore pipelines would be carried out using either fresh water or filtered seawater. Hydrotest chemicals will be selected taking into consideration the best available environmental and technical solutions. Similar to the offshore gas trunkline, additives may include oxygen scavenger, biocide and corrosion inhibitors. Water from onshore pipelines and tank hydrotesting is likely to be disposed of via the export jetty marine pipeline or a temporary pipeline, at controlled rates.

5.2.12 Anti-fouling

A number of vessel operations will be undertaken during the construction, commissioning and operation of the Pluto LNG Development. Under the international maritime convention (MARPOL 73/78) by 1 January 2008 ships either will not be permitted to use tributyltin (TBT) based paints on their hulls or will have a coat that forms a barrier against such underlying compounds from leaching into the marine environment. Therefore, vessels associated with the construction and operation of the Pluto LNG Development will not have TBT-based paints. The potential impact and management of anti-fouling paints is discussed further in **Section 7.8.7**.

5.2.13 Ballast Water

To maintain stability, vessels are equipped with segregated tanks that can be filled with seawater, commonly referred to as ballast water. Ballast water will be discharged during construction from the support vessels, pipelay barge, dredging vessels and during operation from the LNG and condensate export tankers, tugs and support vessels. The potential impacts and management of ballast water is described further in **Section 7.8.8.**

5.2.14 Food Scraps

Food scraps will be generated from all construction and operation related vessels. Prior to overboard discharge, food scraps will be macerated to a diameter of less than 25 mm in accordance with the requirements of MARPOL 73/78 Annex IV.

5.2.15 Waste Water

5.2.15.1 Sewage and Grey Water

Sewage and grey water will be discharged into the marine environment from vessels during construction and operation. Treated sewage and grey water may be discharged to sea from onshore facilities during operations, although onshore re-use options are being evaluated.

Sewage and Grey Water from Marine Activities

During construction, various vessels will be required such as the drill rig, construction barge, dredge and supply boats. Each of these vessels will generate sewage and grey water. The LNG and condensate export tankers visiting Dampier Port during operation will also generate sewage and waste water. Volumes will vary according to the number of personnel accommodated on vessels which will fluctuate; however, greater volumes will generated during construction than operation. All discharges will be in accordance with requirements of the *Pollution of Waters by Oil and Noxious Substances Act 1987* (WA), the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwth) and MARPOL 73/78. The management of sewage and grey water discharges are discussed further in **Section 7.8.13**.

Table 5-18 lists the anticipated volumes of sewage and grey water that would be discharged on a daily basis from each of the vessels associated with the Pluto LNG Development.

The riser platform will not normally be manned during operation; however, short-term stays may be required for maintenance during operation, in which case sewage and grey water will be produced. Sewage and grey water will be macerated to a size less than 25 mm prior to discharge to ocean. No sewage or putrescible waste will be discharged within 12 nm of land.

Sewage and Grey Water from Onshore Activities

During construction, sewage will be generated at both Site A and Site B. The type of sewage treatment facilities that will be used during construction will be determined by the selected

Table 5-18 Sewage and Grey Water Discharge Volumes from Pluto LNG Development Related Vessels

Vessel	Manning level	Estimated Daily Treated Waste (m^3)
Drill rig	120	9
Construction barge	110	8.25
Supply boats	10	0.75*
Dredge	15	1.125*
LNG tanker	25	1.875*

*No discharge within DPA port limits unless MARPOL treatment requirements are met

contractor. It is anticipated that either a large number of portable toilets will be transported to the construction sites or alternatively, a number of temporary in-ground tanks may be installed for the duration of the construction activities. These would be regularly pumped out and the sewage removed and transported to an approved treatment facility. It is anticipated that portable ablution blocks will be provided along the trunkline construction corridors.

During operations, sanitary waste water will comprise both grey water and sewage from the gas processing plant at Site B. Domestic sewage from all buildings will be directed to the domestic sewage collection pits from where the effluent will be pumped to a sewage treatment package. The sewage treatment package at Site B will comprise of a compartmentalised tank and air distribution system. The tank will include three compartments for aeration, clarification and chlorine contact of the sewage. Sludge from the sewage treatment plant will be collected and de-watered (minimum 2% Total Suspended Solids (TSS)) and will be removed by vacuum truck for transport to existing approved disposal facilities in the Pilbara region.

As an indication, a workforce of 150 is estimated to produce approximately 56 m^3/day sewage and grey water with a maximum flow rate of approximately 5.6 m^3/hour. During operations, treated sewage will be discharged via a marine pipeline into Mermaid Sound (**Figure 4-11**). Alternatives to marine disposal of treated sewage generated during operations are being considered, and are discussed in **Section 3.6**.

The impacts and management of sewage and grey water are discussed further in **Section 7.8.13**.

5.2.15.2 Non Routine and Accidentally Oil Contaminated Water

Non routine contaminated water and AOC water is water from bunded area drains, equipment wash down areas and paved areas that may be contaminated with substances such as oil and grease. Non routine contaminated water is produced during events such as maintenance or shutdowns (for example, contaminated washdown water) while AOC water can be produced by spills or accidents. All non routine contaminated water and AOC effluents will be directed to a central basin that provides a means of capturing 'first flush' runoff and separating oil contaminated effluent from clean effluent. Contaminated effluent is then directed to an oil water separator unit, which is expected to be a dissolved air flotation unit or technology with similar efficiency. Oil will be separated and removed for recycling.

Clean water from the central basin and oil water separator unit will be discharged through the marine discharge pipeline into Mermaid Sound (**Figure 4-11**). The volume of water will vary depending on frequency of washdown and rainfall. Consideration of alternatives to marine disposal of treated AOC water and other waste water generated during operations is discussed in **Section 3.6**.

The potential impacts and management of non routine contaminated water and AOC water are discussed further in **Section 7.8.13**.

5.2.15.3 Demineralised Water

Demineralised water is required to provide heat to various components of the gas processing plant. Hot demineralised water will be heated by the Waste Heat Recovery Units and circulated through the gas processing plant (**Section 4.7.5**).

The hot water will initially be sourced from potable water, which will be demineralised leaving an effluent of approximately 1 m^3/hr with slightly elevated salinity. This effluent will be treated as a possible resource for re-use within the gas processing plant.

The demineralised water itself will normally be continually circulated throughout the gas processing plant, with very little discharge under normal operating conditions. Should demineralised water be intentionally discharged (for example, during maintenance) it will be routed via open drains to the waste water treatment plant. Once treated, the demineralised water will be commingled with other treated waste water and discharged into Mermaid Sound. Consideration of alternatives to marine disposal of treated waste water generated during operations is discussed in **Section 3.6**.

5.2.15.4 Produced Water

Produced water is comprised of condensed water and formation water (**Section 4.5.1**). The volume of produced water is expected to peak at approximately 800 m^3/day, of which approximately 160 m^3/day is formation water and the remainder (640 m^3/day) is condensed water.

During the initial years of operation, produced water will be transferred via a subsea gas trunkline from the riser platform to shore for treatment. An onshore produced water treatment system will be provided at Site B to remove contaminants from formation water and condensed water, in order to achieve the desired discharge criteria prior to disposal. The produced water will be treated to achieve a target of less than 5 mg/l total (that is, dispersed and dissolved) hydrocarbon in water as an annual average. Following treatment, produced water will be commingled with other waste waters (**Section 5.2.15**) prior to marine discharge to Mermaid Sound at the end of the jetty (approximately 650 m from the shoreline). Alternatives to disposing of treated waste water to Mermaid Sound are being considered. This is discussed in **Section 3.6**.

Achieving a target of less than 5 mg/l total oil in water content will require a range of treatments which will most likely include production separation, additional de-oiling (by a combination of corrugated plate interceptors, air flotation, macro-porous polymer extraction membranes), bio-treatment and final polishing/filtration. Oil recovered by the front end of the treatment system will be pumped to a slop oil tank for recovery and recycling.

Following construction of the second platform, the wellstream gas and liquids are likely to be transferred from the riser platform to the second compression platform. At this time a portion of the produced water associated with the wellstream fluids will be removed and discharged at the platform location.

5.2.15.5 Summary of Waste Water Discharges

During operation, sewage and grey water will be treated in a sewage treatment plant at Site B, and other waste waters will be treated in the waste water treatment plant. Following treatment, the treated waste waters will be commingled and discharged via a marine pipeline into Mermaid Sound. Alternatives to marine disposal for this treated waste water are being considered, detail of which is provided in **Section 3.6**.

The treated waste water that may be generated during operation of the gas processing plant and storage facilities is summarised by **Table 5-19** and the key characteristics detailed in **Table 5-20**. The volume of non routine contaminated water and demineralised water has not been included, as these discharges will occur infrequently and average volumes are difficult to predict.

Table 5-19 Combined Effluents from Operation of the Gas Processing Plant and Storage Facilities

Liquid	Maximum Daily Average (m^3)	Peak Flow (m^3/hr)
Condensed Water	640	26.7
Formation Water	160	6.7
Accidentally Oil Contaminated Water	60	6.0
Sewage and Grey Water	56	5.6

Table 5-20 Key Characteristics of Combined Liquid Effluent from the Gas Processing Plant and Storage Facilities

Characteristic	Volume (maximum)
Daily Average Volume	954 m^3
Salinity (Total Dissolved Salts)	<6250 mg/L
pH	6–9
Biological Oxygen Demand	5 mg/L
Total Suspended Solids	50 mg/L
Oil in Water	<5 mg / L

5.3 Terrestrial Discharges and Waste

5.3.1 Overview

This section outlines the main waste streams that will be generated or disposed of from the onshore gas processing plant and storage facilities and any wastes generated offshore that require onshore treatment and disposal. The volume of waste predicted during construction will vary depending on the activity. During site preparation at Site B and Site A, large volumes of inert material (for example, soil or rock) will be generated; however, much of this will be re-used on site. Apart from domestic and green waste, volumes of packaging waste (such as plastic, paper and timber) will also be generated.

During commissioning and operation, a variety of liquid and solid waste streams will be generated as by-products in the LNG process and will require routine discharge. Typical waste streams generated from gas processing plants for all Development phases are outlined in **Table 5-21**.

5.3.2 Domestic Waste from Marine Activities

Non-hazardous solid waste will be generated during construction, commissioning and operation, and will include waste from the riser platform, drill rig, support and supply vessels, pipelay barges and dredging vessels. Solid waste generated offshore will include packaging materials such as cardboard, drums, plastics as well as construction type material such as scrap metal, thread protectors from casings and used personal protective equipment. General domestic waste streams will also be generated from accommodation facilities including aluminium cans, magazines, plastic and packaging.

All solid wastes other than drill cuttings and food scraps will be returned to shore for disposal/ recycling in accordance with State and local regulatory requirements. Likely volumes of solid waste will depend on the number of personnel and type of activity (construction, maintenance, drilling and shut downs). The largest volume of solid waste is likely to be generated during the construction phase. The potential impacts and management of solid waste is discussed in **Section 7.8.9**.

Table 5-21 Summary of Key Terrestrial Discharges and Waste

Terrestrial Discharge/ Waste	Construction Phase (3–4 years)	Commissioning Phase (<1 year)	Operation (30 years)	Decommissioning Phase
Domestic waste from marine activities	✓	✓	✓	✓
Domestic waste from onshore activities	✓	✓	✓	✓
Green waste	✓			
Hazardous waste from marine activities	✓	✓	✓	✓
Hazardous waste from onshore activities	✓	✓	✓	✓

5.3.3 Domestic Waste from Onshore Activities

Common wastes such as domestic and packaging waste are likely to be generated throughout the life of the Development, while a number of specific waste items will be generated only at certain stages of the Development. During construction activities the main domestic wastes will comprise packaging and putrescibles. Other common solid wastes likely to be generated during construction may include glass, scrap metal, cable reels, pallets, cardboard, plastic, empty drums, personal protective equipment, danger tape and safety tags, concrete and construction rubble, used garnet sand, spool protectors, office materials and aluminium cans. Food wastes will also be generated from the temporary mess facilities during construction. The construction and operation workforce will be accommodated off-site at existing accommodation in Dampier and Karratha, and food wastes from these sources will be managed by existing waste services provided by the Shire of Roebourne.

During operations, routine operational waste volumes are likely to be relatively minor in comparison to the waste generated during construction activities. The main domestic wastes from operations will include packaging waste (for example, bottles, cardboard, aluminium cans and plastic) and food wastes from a permanent onsite mess at Site B.

Any inert waste will be re-used wherever possible.

5.3.4 Green Waste

Green waste will be generated at the gas processing plant area (Site B) and along the trunkline corridor during site preparation for construction and pipe laying. Once operational, it is unlikely that the Pluto LNG Development will generate green waste. The impacts and management of green waste are discussed further in **Section 9.4.1**.

5.3.5 Hazardous Waste from Marine Activities

Hazardous waste that may be generated offshore include antifouling paints, drilling fluids, well completion fluids, fluorescent tubes, batteries, spill clean up material, biological waste from medical facilities, waste paints, empty chemical containers (for example, aqueous foam fire fighting), oily waste water and grease from routine maintenance activities. The largest volume of hazardous wastes will be generated during the construction and commissioning phases, with smaller volumes produced during operational activities such as routine maintenance.

All hazardous solid wastes will be returned to shore for disposal/ recycling in accordance with State and local regulatory requirements. The potential impacts and management of hazardous wastes are discussed further in **Section 7.8.10**.

5.3.6 Hazardous Waste from Onshore Activities

Typical hazardous wastes that are likely to be generated during construction and operation phases are described in **Table 5-22**.

During construction a range of hazardous wastes will be generated. Timber treated with methyl bromide or copper chromated arsenate may be generated from packaging associated with imported gas processing plant components, as these chemicals are used as part of quarantine practises. Insulation waste from pipe cladding is likely to be generated at specific stages of the construction phase. Other flammable materials such as empty paint storage containers will also be generated throughout construction.

Medical wastes will be generated in low volumes during both construction and operation from medical centres on an ongoing basis, and other hazardous wastes such as fluorescent tubes, coolant, solvent and batteries will be generated throughout the life of the Development.

The key hazardous waste likely to be generated during operation and indicative waste volumes are outlined in **Table 5-23**.

Table 5-22 Summary of Key Hazardous Waste Streams during Construction and Operation

Key Hazardous Waste Streams from Facilities	
Mercury filters	Activated methyldiethanolamine (aMDEA)
Waste oils	Hydrocarbon contaminated materials
Grease	Spill clean up material
Salts recovered from MEG regeneration	Coolants
Laboratory and photographic chemicals	Biological wastes
Oil sludges, filters, rags etc	Excess or spent chemicals
Oily waste water	Empty chemical containers
Paints	Methyl bromide or copper chromated arsenate treated timber
Off specification condensate	Spent x-ray films and developing materials
Contained spilt liquids	Batteries
Spent solvents	Fluorescent
Spent molecular sieve material	

Table 5-23 Indicative Hazardous Waste Volumes for Operation of the Pluto LNG Development

Waste	Quantity	Frequency of Generation
Waste lubricating oils	8 500 kg/yr	Once in two months
Spent oils	950 kg/yr	Continuous
Oily sludge/ float	40 000 kg/yr	Once a week
Spent solvents	100 kg/yr	Continuous
Molecular sieve waste	35 380 kg/yr	Bed life is three years
Mercury contaminated adsorbent	14 m^3/yr	Bed life is six years
Activated carbon	33 020 kg/yr	Continuous
Waste oil from slop oil tank	4 m^3/yr	Twice a year
Waste water from waste water tank	100 m^3/yr	Twice a year
Medical waste	500 kg/yr	Continuous
Spill cleaning materials	100 kg/yr	Intermittent
Slug catcher bottoms	1000 kg/yr	Once in five years
NAG trunkline filter	1 (no.)	Once in three years
AGRU-solvent filters	3 (no.)	Once in five years
Molecular sieve guard filter	2 (no.)	Once in five years
C3 and C4-product filters	2 (no.)	Once in five years
Flare knock-out drum bottoms	64 000 kg/yr	Occasionally

The MEG reclamation process will generate some insoluble salts which cannot dissolve into water and are removed to prevent potential scale deposits in the downstream systems (**Section 4.7.5**). These salts will comprise mainly barium, strontium and calcium carbonate in relatively small volumes. Investigations are ongoing into the options available for disposal of these salts.

The gas processing plant will contain a mercury removal unit (**Section 4.7.3**). The unit is a vessel containing activated carbon beds which absorb mercury contained with the gas. The carbon beds and catalysts will require periodic removal and return to the supplier for recycling, or alternatively will require disposal at an existing, approved hazardous waste reception facility.

The impacts and management of hazardous wastes are discussed further in **Section 9.4.2**.

Existing Marine Environment 6

6.1 Studies and Surveys

An extensive research programme has been conducted on biological and physical aspects of the deep water and nearshore marine environments as part of Woodside's environmental review of the proposed Development Area. Studies have included:

- A sea turtle habitat survey at Holden Point Beach undertaken by Pendoley Environmental (Pendoley 2006).
- An offshore marine environmental survey (SKM 2006c) within the Pluto gas field and platform area, including infauna and epifauna sampling, sediment sampling for particle size analysis and sediment chemistry and ROV/video investigations of benthic habitats. Opportunistic sightings of seabirds, cetaceans and other marine mammals, turtles and other reptiles and large fish were also recorded.
- Sampling and assessment of sediment chemistry characteristics in proposed dredging areas.
- A marine environmental survey conducted by SKM covering benthic habitats of the proposed navigation channel in Mermaid Sound and the spoil disposal grounds (in **Section 6.3.1** and **Section 7.9.5**)
- A sediment dispersion study undertaken by Asia-Pacific Applied Science Associates (APASA) to predict the fate of sediment mobilised from dredging and dumping activities and to identify potential impacts in relation to coastal sensitivities (APASA 2006a).
- A waste water assessment undertaken by Rob Phillips Associates to identify spatial and temporal impacts of discharging treated waste water into the marine environment (Rob Phillips Associates 2006).
- A quantitative hydrocarbon spill exposure assessment undertaken by APASA to assist in determining predicted fate and affects of potentially spilled hydrocarbons into the marine environment (APASA 2006b).
- Deployment of an underwater noise logger at the Pluto gas field to record ambient noise characteristics. Biotic noises, such as whale vocalisations and fish choruses, will also be recorded to assist in establishing an inventory of species present in the area and subsequent analysis of recorded noise will be undertaken by Curtin University.

Other investigations included desktop studies on marine mammals, climate condition, bathymetry and the oceanographic environment. General literature reviews and searches of key data sources, including the Western Australia Museum, Department of Environment and Conservation (DEC) databases, WA Department of Fisheries, Department of the Environment and Heritage (DEH) databases and reports from the Australian Institute of Marine Science (AIMS), were also undertaken.

6.2 Physical Marine Environment

6.2.1 Climate and Meteorology

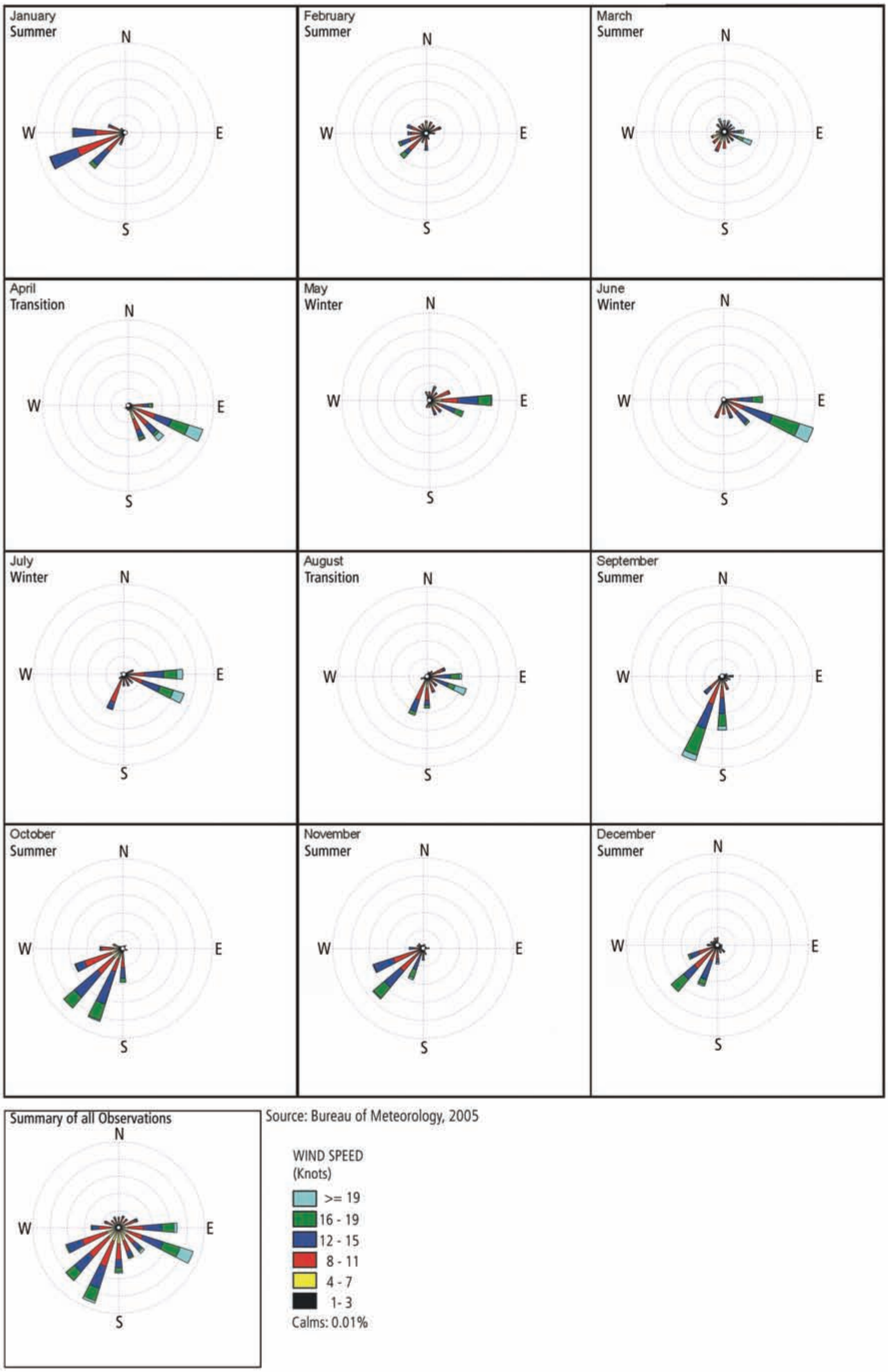
During summer, prevailing winds are from the north-west and south-west, changing to south-easterlies over winter. Mean water temperatures range from 23°C in winter to 28°C in summer, and there is relatively low rainfall, although heavy downpours can occur during tropical cyclones and depressions.

Since 1973, Woodside has collected extensive meteorological records from the offshore gas facility North Rankin A, approximately 70 km north-east of the Pluto gas field. A subset of this data, together with data from the Barrow Island meteorological weather station, is presented below as a general guide to the climatic conditions in the offshore marine environment.

Mean daily temperatures at the North Rankin A facility range between 23°C in winter and 28°C in summer. Average annual rainfall measured at Barrow Island is 320.3 mm, with June receiving the highest monthly average of 64.6 mm (BOM 2005).

The predominant winds offshore are south-westerly from September to March and easterly and south-easterly from May to July. During the transition months (April and August) winds tend to be lighter and prevail from a south-west and south-east direction. **Figure 6-1** shows monthly wind roses for North Rankin A, where average winds speeds are 5.6 m/s over the whole year.

Figure 6-1 Wind Roses for the North Rankin A Offshore Facility on the North West Shelf



Storm Surge

Storm surges are caused by cyclonic winds blowing across the sea surface and a fall in atmospheric pressure. Lower pressure is typically experienced at the eye of a cyclone, thereby allowing a rise in relative sea level in, and close to, the cyclone centre. This raised dome-like mass of water can be up to 60–80 km in diameter and 2–5 m higher than normal sea level. As a cyclone nears the coast, low-lying areas may experience flooding due to strong onshore winds which have displaced the storm surge ahead of the cyclone's centre (CSU 2001). A number of storm surge studies have been conducted in the vicinity of the Burrup Peninsula. The Karratha Storm Surge Inundation Study, undertaken by the BOM in 1996, indicated that a water level of up to 4.8 m AHD is likely to result from a 1–in–100 year event within the King Bay–Hearson Cove Industrial Area. In comparison, the township of Karratha is likely to experience a water level of 6.2 m AHD for a 1–in–100 year event, given its more exposed location (BOM 1996).

6.2.2 Hydrography and Oceanography

Bathymetry

The Pluto LNG Development is located on the North West Shelf which comprises 95 000 km^2 of continental shelf extending from the North West Cape to the Arafura Sea. The bathymetry of the offshore development area is characterised by three distinct features: the continental shelf, the continental slope and the abyssal plain. The continental shelf extends approximately 150 km offshore as far as the Pluto gas field. At the 200 m isobath the shelf 'break' indicates the start of the continental slope and the seabed drops away sharply to depths of 4000–5000 m. **Figure 6-2** shows the bathymetry of the North West Shelf, while the bathymetry in the area of the Pluto gas field is presented in **Figure 6-3**.

The Pluto gas field is situated on the continental slope between the continental shelf and the abyssal plain. The water depth across the permit ranges from approximately 150 m to 1000 m. A key feature of the field area is a number of submarine canyon systems. These features trend east-west across the continental slope and have an increased seafloor gradient of up to 80°, compared to the continental slope (around 7°). These canyons can be clearly seen on the 3D bathymetry chart in **Figure 6-3**.

The riser platform will be located on the continental shelf, between 80 m and 85 m water depth, in an area that is relatively flat and featureless.

The gas trunkline will traverse the continental shelf as the seabed slopes up gently from the platform area to the edge of the Dampier Archipelago where depths then decrease relatively rapidly from approximately 30 m, west of Enderby and Rosemary Islands, to around 10 m in Mermaid Sound and Mermaid Strait.

The Dampier Archipelago is entirely contained within the 30 m isobath and has a relatively complex bathymetry. The bathymetry of the Dampier Archipelago is relatively well surveyed with information available from Admiralty charts and several commercial surveys, such as Racal Survey Australia (1994) and Geofound Pty Ltd (1994). The main relevant bathymetric features identified in these surveys include:

- water depths in Mermaid Sound ranging from approximately 6–15 m with isolated rocky outcrops rising to within 3–4 m of the sea surface
- natural deep water channels of approximately 12 m existing at the approach routes into Mermaid Strait from the north, passing between the islands of the Dampier Archipelago
- water depths of 10 m in Mermaid Strait, but also an extensive shoal area with depths of less than 8 m in the central area of the Strait.

Figure 6-2 Regional Bathymetry of the North West Shelf

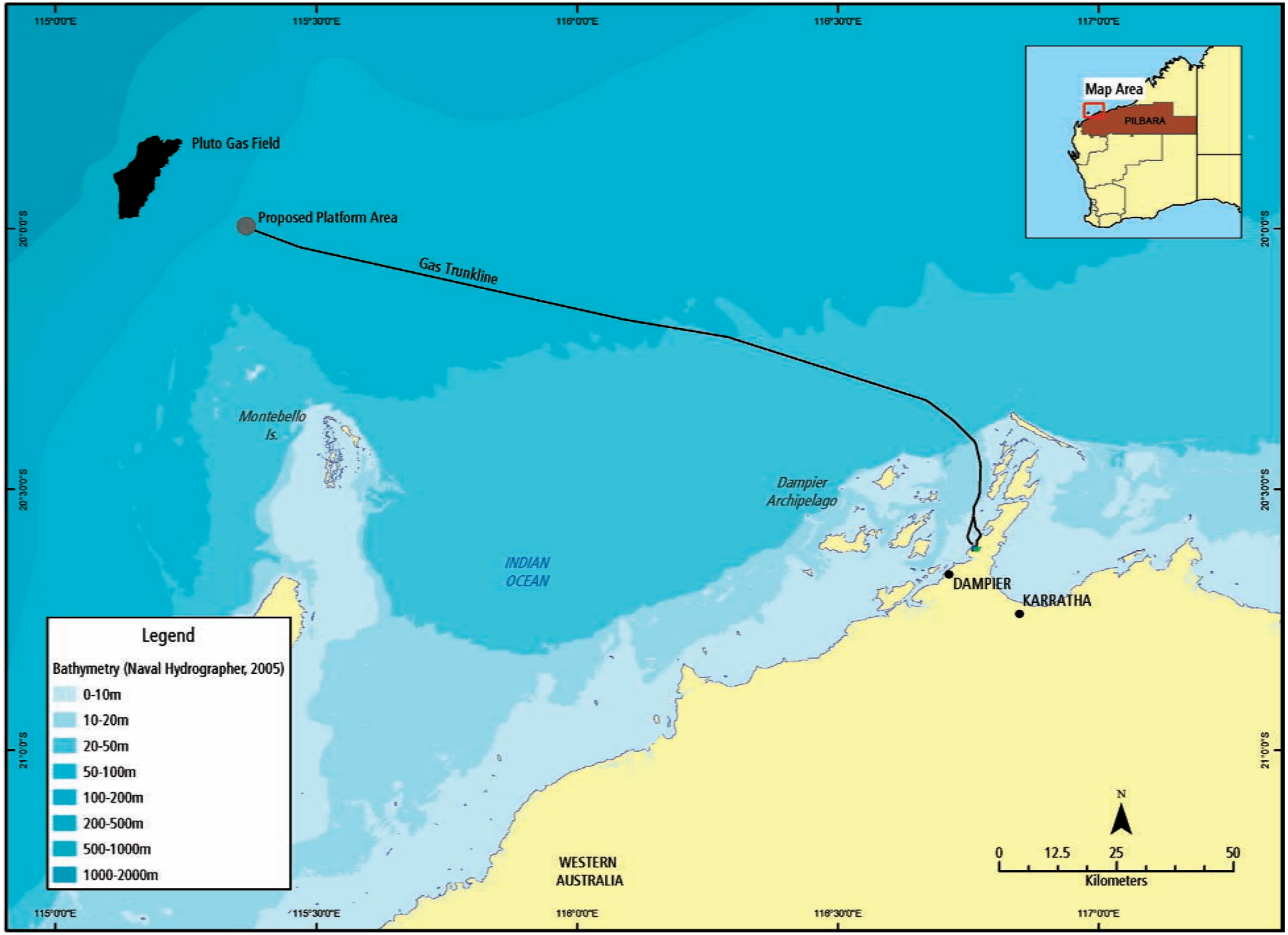
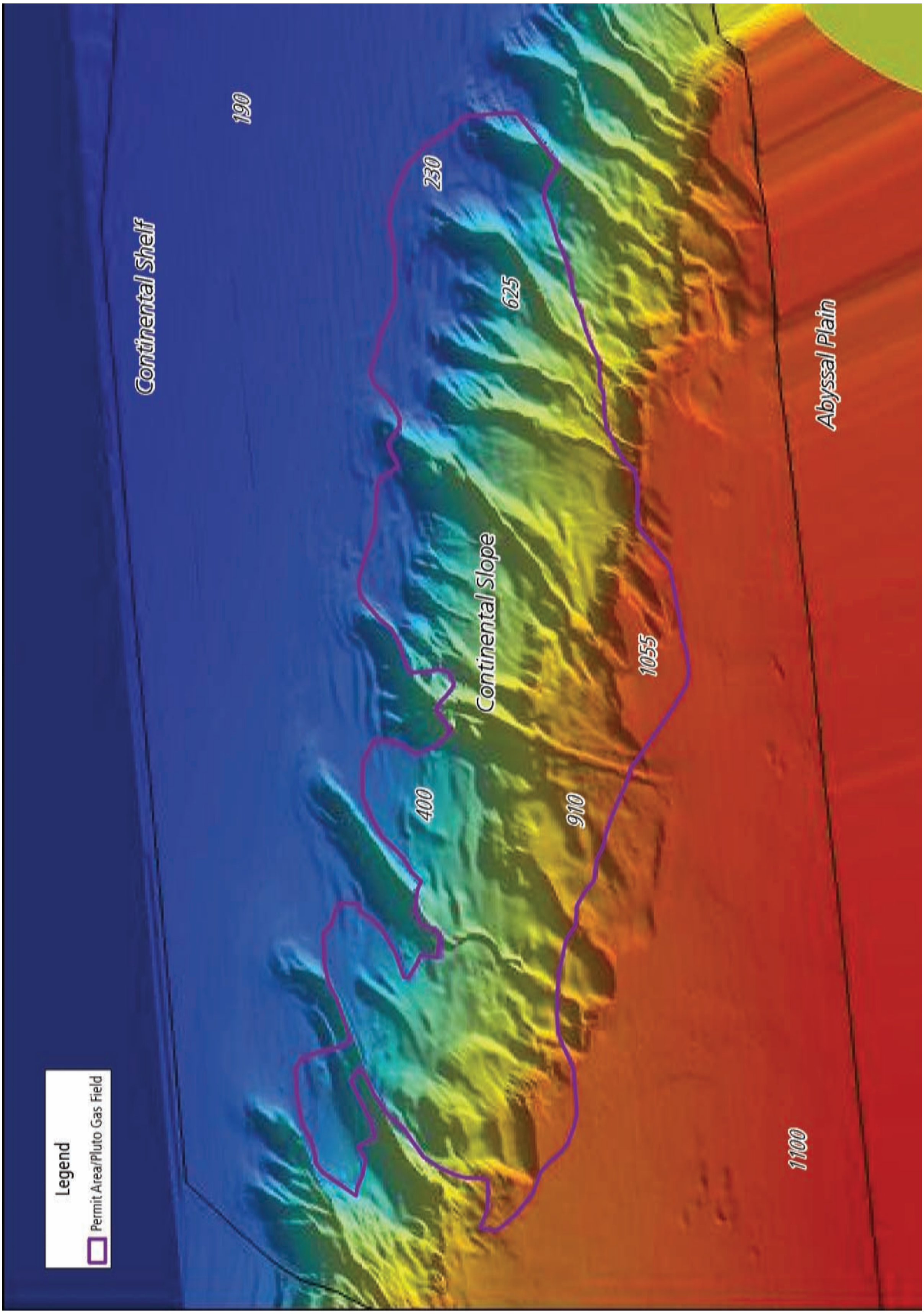


Figure 6-3 Bathymetry at the Pluto Gas Field



Currents and Water Circulation

Water circulation on the North West Shelf is influenced by the broader scale circulation of the Leeuwin Current to the west (Godfrey and Ridgway 1985; Batteen et al. 1992) and the Indonesian Throughflow to the north (Cresswell et al. 1993; Meyers et al. 1995). These flows carry warm low salinity water in a south-westerly direction along the outer North West Shelf from February to June (Holloway and Nye 1985; Holloway 1995).

The Leeuwin Current is approximately 300 m deep and generally moves at about 1 knot (50 cm/s), although speeds of 2 knots (1 m/s) are also common. The Indonesian Throughflow is made up of a series of ocean currents which flow from the tropical Western Pacific Ocean through the Indonesian Seas into the South Indian Ocean. The Indonesian Throughflow is an integral element of the global ocean circulation influencing regulation of climate and rainfall across Indonesia and Australia.

Strong winds from the south-west cause intermittent reversals of the Leeuwin Current and Indonesian Throughflow from July to January; with occasional weak upwelling of cold deep water onto the Shelf.

Daily current patterns on the North West Shelf and in the vicinity of the Pluto gas field tend to be strongly dominated by large tidal motions with wind forced currents only becoming dominant around the neap tide. Analysis of CSIRO (2006) data for the Pluto gas field region shows that non-tidal currents are typically seasonal in nature as shown in **Figure 6-4** and **Figure 6-5** and that surface currents are typically stronger than currents through the water column. These figures also indicate that the surface and subsurface oceanic currents in the Pluto gas field region predominately flow along the shelf break (either north-eastwards or south-westwards) and while other flow directions are possible, they are short lived and occur as a result of passing shelf edge eddies often associated with large scale oceanic boundary flows.

The combination of large tides and strong stratification can also generate internal waves over the upper slope of the North West Shelf (Craig 1988). The amplitude of the internal waves can be as large as 100 m near the continental shelf break and the associated currents comparable to the barotropic tide, with evidence of significant bottom intensification (Holloway and Nye 1985; Holloway 2001). Dissipation of these internal waves is also expected to greatly enhance vertical mixing rates.

Currents in the Dampier Archipelago are dominated by tidal currents and wind forcing. The shallowness of the Archipelago means that winds contribute more to generation of currents than in offshore waters. Local winds can impart motion to surface waters quickly and constant winds are able to alter the entire water column after several hours (Pearce et al. 2003).

Upwelling

Upwelling is the upward movement of cold, deep water towards warmer surface waters. Large canyons and areas of the upper slope that are relatively steep have been associated with significant upwelling and water mass exchange. The actual extent of this influence across the continental shelf break is unknown, although there is some evidence that enriched water masses move from the shelf break into the water at 50 m depth (Heyward et al. 2000). Upwelling on the North West Shelf is rarely observed and may not show on the surface due to the warm, relatively fresh body of water introduced by the Leeuwin Current (Heyward et al. 2000; A Heyward [AIMS] 2005 pers. comm., 17 November). Upwelling in the area of the Pluto gas field may occur in canyon areas, but may be associated with internal waves as opposed to being a seasonal event.

Upwelling is influenced by regional currents, such as the Leeuwin Current, which vary in intensity with the effects of the El Nino Southern Oscillation (Heyward et al. 2000; A Heyward [AIMS] pers. comm., 17 November 05).

Tides

Tides on the North West Shelf are semi-diurnal (two tidal cycles per day), with currents flooding toward the south-east and ebbing toward the north-west. At North Rankin A there is a distinct spring-neap cycle, with maximum currents ranging from 0.4 m/s on a spring tide to 0.1 m/s on a neap.

Tides within the Dampier Archipleago are also semi-diurnal, with mean low water neap and mean high water spring tides ranging from 0.8 m to 4.5 m; however, astronomical tides can be much higher (up to 5.1 m) (Pearce et al. 2003). Tidal current flow in the Burrup Peninsula region is locally influenced by the surrounding islands and channels that form the Dampier Archipelago. Mills (1985) demonstrated that the strongest tidal currents generally occur near the outer extremities of the Archipelago, particularly in the channels immediately adjacent to the south-west end of Enderby Island (75 cm/s). It was also shown that tidal currents diminished towards the north-west of Mermaid Sound (45 cm/s) and are generally weakest in the innermost reaches of the Dampier Archipelago, except in some of the inter-island passages.

Wave Climate

Waves on the North West Shelf are predominately from a south-west direction with swell height averaging 1–2 m and rising to 3 m during the winter months of June–August. During winter, storm events in the lower Indian Ocean generate swell which can attenuate into a low, consistent, long period wave form as it approaches the Dampier Archipelago (Woodside 1998). Wave heights typically reduce by at least 50% as they propagate down Mermaid Sound from the open ocean (Pearce et al. 2003). Minor waves in the Dampier Archipelago are generated by westerly winds in summer, while the western shores of the Burrup Peninsula and the islands to its north are protected from the persistent winter easterlies (Woodside 1998). From December to April, intense low pressure systems and extreme winds associated with cyclones can generate swell conditions in excess of 8 m height.

Figure 6-4 Current Rose Plots (Yearly and Monthly) of the Near Surface in the Region of the Pluto Gas Field. Plots Show the Direction Toward Which the Prevailing Current Flows.

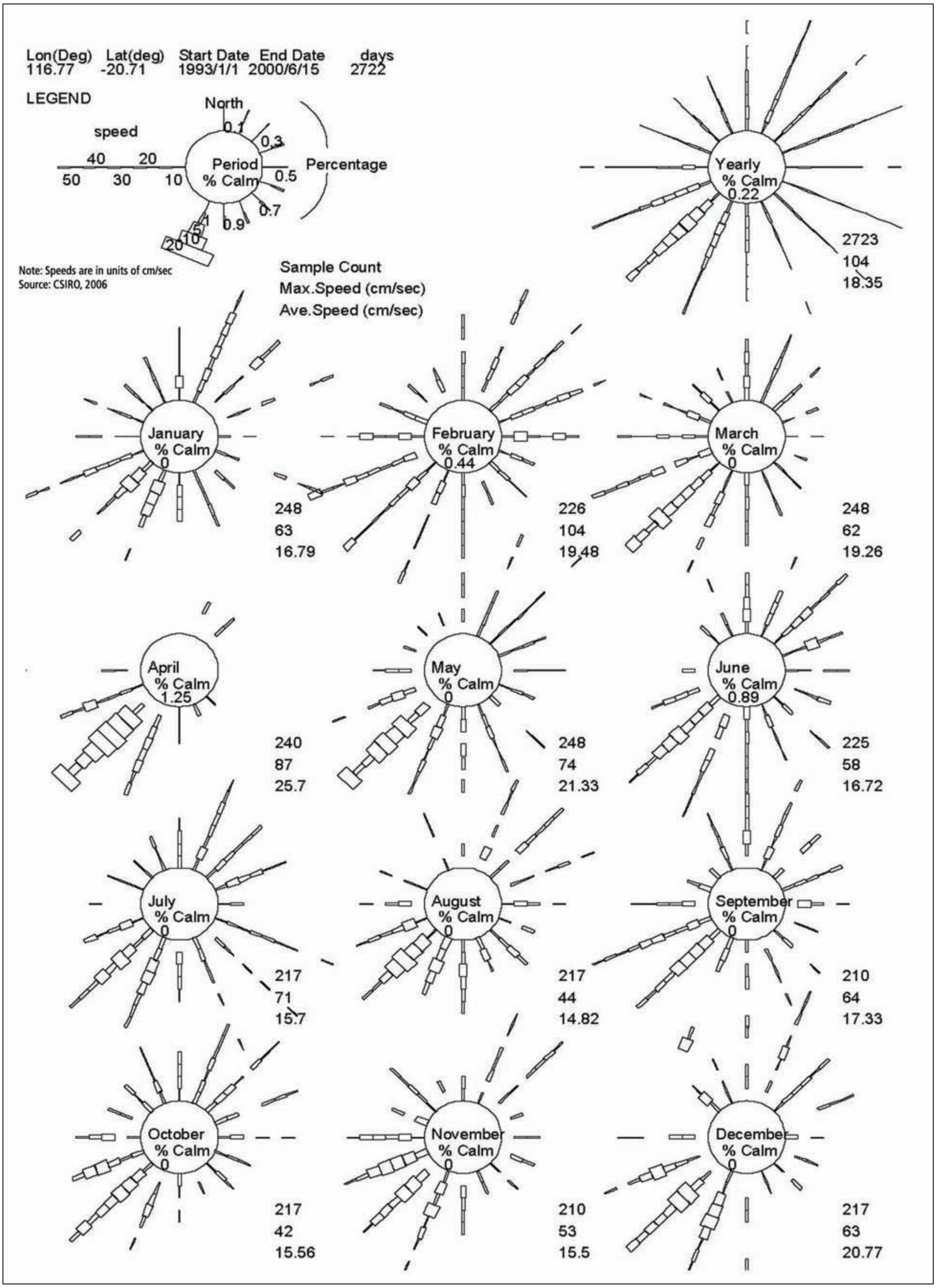
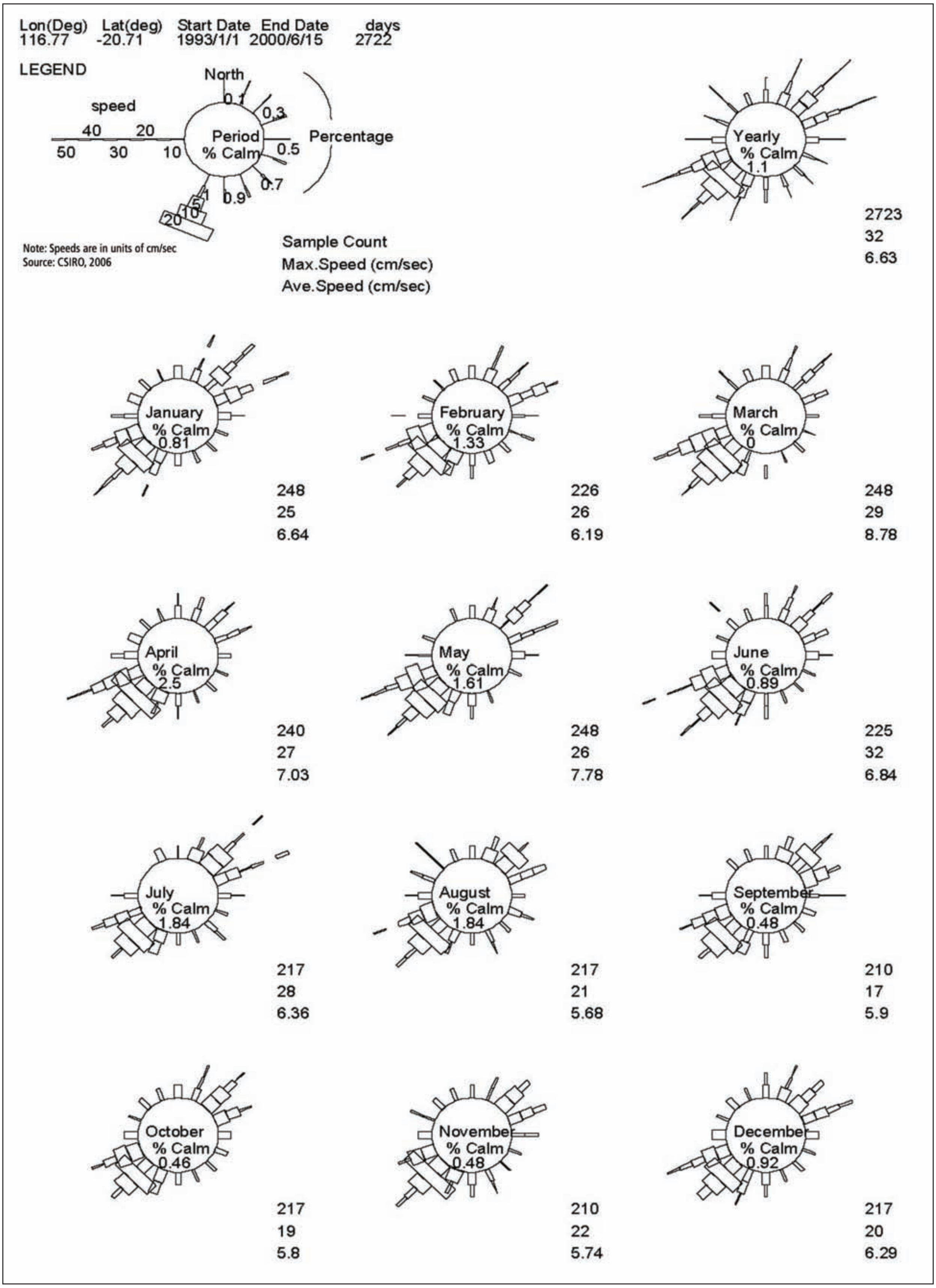


Figure 6-5 Current Rose Plots (Yearly and Monthly) of the Subsurface (Mid Depth) in the Region of the Pluto Gas Field. Plots Show the Direction Toward Which the Prevailing Current Flows.



6.2.3 Water Quality

Levels of Ecological Protection

The majority of Mermaid Sound, according to the Environmental Quality Management Framework set out by the DoE (2006a), is afforded a high to maximum Level of Ecological Protection. Areas around wharves, jetties, ship turning basins (such as the Karratha Gas Plant nearshore infrastructure) and dredge spoil disposal grounds (such as spoil ground A/B) have been allocated a moderate Level of Ecological Protection. Areas around marine discharges are allocated low to moderate Levels of Ecological Protection.

Trace Metals and Organics

A recent study by the former Department of Environment (DoE) (now the DEC) indicated that the coastal waters of the North West Shelf generally have very low levels of anthropogenic contamination (McAlpine et al. 2004). The study measured dissolved concentrations of cadmium, chromium, copper, lead and zinc, total mercury, PAHs, phenols, BTEX chemicals and petroleum hydrocarbons. The survey was conducted in winter and while it provides a 'snapshot picture' of water quality of the North West Shelf and within the Dampier Archipelago, it should be noted that factors such as tidal currents, wind and swell conditions can significantly influence water quality. Water quality in the Dampier Archipelago met the guidelines for a 'very high' level of ecological protection (99% species protection) based on the recommended guidelines and approaches in ANZECC and ARMCANZ (2000). At the time of sampling, all metals measured in King Bay, adjacent to an industrial centre, achieved the national guidelines for 99% species protection, although cadmium, copper and zinc were elevated compared to all other sites surveyed in the Dampier Archipelago. Offshore waters on the North West Shelf are expected to be of high quality given the distance from shore and lack of terrigenous inputs.

The DoE study found no detectable levels of organics in the waters of the Dampier Archipelago; however, natural oil seeps are known to occur on the North West Shelf, with the amount of hydrocarbons entering the ocean from this source estimated at 3300 tpa based on global geological considerations (CSIRO 2002). The ecological impacts of these seeps remain largely unknown.

Temperature and Salinity

Waters of the North West Shelf are usually temperature stratified, with sea surface temperatures (SST) attaining a mean temperature of 29.3°C in March, dropping to 24°C in August (Pearce et al. 2003). In December, temperatures generally exhibit a linear gradient in the surface mixed layer with a thermocline at about 50–100 m. A bottom mixed layer occurs at depths of approximately 400 m where temperatures drop to around 5°C (JEMS 2004). In the cooler winter months (June–August) the surface mixed layer is expected to deepen as SST drops; however, introduction of warm water associated with the Leeuwin Current dampens any seasonal variability.

Nearshore, in the semi-enclosed waters of the Dampier Archipelago, temperature means vary from 22.5°C in July/August to 30.4°C in February (Pearce et al. 2003). During summer, these shallow coastal waters are warmer than offshore waters because of a net input of heat from the sun and atmosphere. This cross–shelf temperature gradient reverses in winter when strong heat loss to the atmosphere and differential cooling occur, resulting in coastal waters becoming cooler than those offshore.

Increases in SST (>30°C) during 1994 and 1998 in the Dampier Archipelago have been correlated with relatively minor coral mortality attributed to bleaching incidents (loss of symbiotic algae) (Blakeway 2005).

Salinity generally remains relatively uniform (34.6–35.6 ppm) over most of the North West Shelf (Pearce et al. 2003; JEMS 2004). Around 10 km west of the Pluto gas field the water column exhibits a subsurface salinity maximum (approximately 35.6 ppm) at 200 m depth before declining to about 34.6 ppm at 400 m depth and exhibiting a linear gradient throughout the bottom mixed layer (JEMS 2004).

Within the Dampier Archipelago, throughout the year, surface salinity decreases from inshore (about 36.7 ppm west of King Bay in March) to further offshore (about 35.5 ppm, 35 km north of East Intercourse Island in March). As described previously, Mermaid Sound displays a 'winter hydrographic regime' whereby denser (cooler and more saline) water forms within the Archipelago, and wedges seaward beneath open Shelf waters. During summer, a 'summer hydrographic regime' is characterised by vertical stratification on the open continental shelf and elevated salinity in shallower coastal waters (Pearce et al. 2003).

Cyclones and heavy rainfall events can result in dilution of salinity within the Dampier Archipelago as a result of runoff including increased flows from the Maitland River. During the passage of Cyclone Monty in March 2004, when Dampier and surrounding areas experienced very heavy rainfall and runoff (over 300 mm in 24 hrs), surface water salinity in Mermaid Sound dropped to approximately 20 g/L (equivalent to 20 ppm), remained low for several days and was identified as a major factor leading to a reduction of up to 95% in live coral cover in some areas of the Dampier Archipelago (Blakeway 2005).

Turbidity and Total Suspended Solids

Turbidity is a measure of the amount of light scattering through water caused by suspended material in the water column. Suspended material varies according to water movement and sediment type. In contrast, Total Suspended Solids (TSS) is a measurement of the mass of suspended solids in the water column.

The offshore reefs of the Dampier Archipelago are characterised by a relatively clear water column, however waters of the inner Archipelago experience naturally higher levels of turbidity as a result of local re-suspension of fine sediments caused by wind and tidal mixing, with levels being highly site dependant

(Stoddart and Anstee 2004). **Figure 6-6** shows natural turbidity through Flying Foam Passage during a spring tide. High levels of natural turbidity also occur during and after cyclones and rainfall events as a result of wave action and run-off (**Figure 6-7**). Levels of suspended solids throughout various locations in the Dampier Archipelago, recorded by Woodside before and after dredging for the NWSV second trunkline, ranged from 1–18 mg/l during periods of pre and post dredging (when TSS levels were considered as being unaffected by dredging operations).

High turbidity levels within the shallow areas of the Dampier Archipelago are also, at times, associated with vessel propeller wash and associated sediment re-suspension. Berthing activities also generate turbidity in the water column that can extend several hundred metres from a vessel depending on the tidal conditions at the time. **Figure 6-8** shows high turbidity in the Dampier Archipelago as a result of ship movements in a shipping channel in Mermaid Sound.

Natural sedimentation levels as high as 240 mg/cm^2/d averaged over five consecutive days (highest single value was 330 mg/cm^2/d) have been observed in Mermaid Sound without any corresponding coral impact (IRCE 2004a).

Nutrients

The waters of the North West Shelf region are oligotrophic with low availability of nitrogen limiting rates of primary production (refer to **Section 6.3.2**). Generally, negligible nitrate is found in the surface mixed layer (up to 100 m water depth), below which concentration increases up to ~250 mg N/m^{-3} at depths of around 300 m (Herzfield et al. 2003).

Nutrient fluxes into the bottom of the surface mixed layer are, however, a regular occurrence. These fluxes are thought to be related to tidal mixing and to the upwelling of deep offshore waters, near the shelf break, with some evidence indicating that enriched water masses move from the continental shelf break across the North West Shelf into waters at 50 m depth. It is rare for these nitrate rich waters to intrude onto the North West Shelf further than the 50 m isobath as a result of these processes, and the fluxes of nutrients are roughly constant throughout the year (Heyward et al. 2000), though are probably not seasonal but more likely associated with internal waves (refer to **Section 6.2.2**).

Upwelling events may supply about half the nitrogen input of the Shelf, with additional nitrogen coming from mixing during cyclones and recycling (Holloway et al. 1985).

Waters in the Dampier Archipelago are also considered oligotrophic however on occasions, blooms of nitrogen-fixing microbes such as Trichodesmium or mangrove mud-flat cyanobacterium may contribute significant amounts of nutrients into the marine environment. High spatial and seasonal variability are evident in nutrient and chlorophyll-*a* concentrations within the Dampier Archipelago (Pearce et al. 2003). Orthophosphate concentrations in the Dampier Archipelago are generally between approximately 0.02 and 0.25 µM/L; however, a peak was recorded in June 1981 of more than 4.0 µM/L.

Figure 6-6 Natural Turbidity in Flying Foam Passage Looking North Towards Angel Island (DPA 2004a)

Figure 6-7 High Turbidity in the Dampier Archipelago after a Cyclone Looking North Towards Legendre Island (DPA 2004a)

Figure 6-8 Turbidity from Shipping Activity Looking North-East Toward a Ship Berthed in Dampier Harbour (DPA 2004b)

6.2.4 Seabed Morphology

Regional Seabed Morphology

The outer continental shelf and slope of the North West Shelf is a predominantly featureless soft sedimentary environment. However, the sediment bed texture changes markedly across the Shelf. In the relatively high-energy environment of the mid-shelf region there are high concentrations of gravel and sand fractions, but conditions are less energetic on the outer-shelf, which is comprised of loose, silty carbonate sands and accumulated clay fractions (URS 2001; Margvelashvili et al. 2004).

Sediments of the inner shelf can be broadly categorised as (Woodside 1997):

- coarse sand overlaying calcarenite typically at depths of between 1 and 5 m beneath the surface sediment
- isolated, hard rocky habitat associated with emergent calcarenite features at depths of 50 to 80 m.

The closest known emergent seabed features to the Pluto gas field are the Rankin Bank Shoal to the east, which rises 20–25 m from the sea surface and Tryall Rocks, an area of exposed reef near the Montebello Islands. Both features are more than 30 km from the Pluto gas field.

Pluto Gas Field Seabed Characteristics

A site specific survey (SKM 2006c) was conducted to investigate the benthic characteristics at the Pluto gas field location. A benthic grab (box corer) and epibenthic sled were used to determine habitat composition, biota distribution and abundance, particle size distribution and sediment chemistry within the Pluto gas field and offshore development area. A remotely operated vehicle (ROV) was used to collect footage of the seabed for assessment of the broad scale benthic habitats of the Pluto gas field and offshore development area.

The majority of the substrate within the Pluto gas field consisted of soft sediments, which are green-grey in colour below about 400 m and a light brown in shallower depths and are expected to be typical of the region. Sediments were found to be composed of silt below about 400 m with fine sand above this depth. Seabed gradients vary from flat to gradients in excess of 80° within submarine canyons. Results from the geotechnical and geophysical survey of the Pluto gas field indicate that the seabed of the Pluto gas field is generally devoid of hard substrate, except for two areas of seabed which are discussed below.

The main area of exposed hard substrate occurs in about 1000 m depth where deep water cliff-like structures occur at the meeting of the continental slope and the abyssal plain (**Figure 6-9**). These underwater sea cliffs form part of the canyons discussed in **Section 6.2.2**. The bottom of these rocky cliffs is situated in about 1050 m water depth with an almost vertical wall extending 20 m up to about 1030 m at the surveyed location. The rock appears to be sedimentary with clear bands or layers occurring in the rock profile (**Figure 6-9**).

From about 1030 m to 880 m, rock and mudstone outcrops occur, interspersed with large areas of soft sediment. The mudstone is quite flat in areas with limited vertical relief and the sediment build up on the exposed rock and mudstone is minimal, suggesting that sediment movement down the slope is very limited and/or that strong currents sweep away exposed sediments. The mudstone itself is very soft, disintegrating very easily when handled by an ROV manipulator arm.

The only other exposed hard substrate known to occur in the Pluto gas field is a series of rock pinnacles located around 300 to 500 m depth (**Figure 6-9**). Remotely operated vehicle investigations suggest that these structures are biogenic in origin, created by a deep water coral which has been identified as a species of *Lophelia*. Results from the geotechnical studies indicate that there are a number of these pinnacles spread over an area of about 5 km x 1 km. Remotely operated vehicle investigations indicate that these structures are generally 2–3 m tall and 1 m wide.

The proposed platform location is in an area of 80 to 85 m water depth. Ongoing investigations are required to determine the exact final positioning. For the purposes of assessment it is assumed that the platform will be located within a 2 km radius of the centre point given in **Table 4-2**. Geotechnical surveys indicate the seabed in this area is relatively flat with surface sand 1–4 m thick overlaying weakly cemented sands. **Figure 6-10** presents a 3D representation of bathymetry that illustrates the presence of sand waves across the platform area.

Gas Trunkline Route Seabed Characteristics

Preliminary geotechnical investigations have been undertaken along the gas trunkline route (Golder 2006). The material recovered during these investigations were predominantly fine sand with variable proportions of coarser sand fractions, silt, shells and shell fragments, coral cemented materials (including calcarenite gravel and cobbles). Interpretation of these results has identified five general zones of subsurface seabed (**Table 6-1** and **Figure 6-11**).

Further inshore and within the Dampier Archipelago, the seabed consists of (AGC Woodward-Clyde 1994):

- Holocene calcareous sands
- Pleistocene to Holocene alluvial and colluvial deposits, gravel and sand, and limestone conglomerates
- Pleistocene dune limestone laterally passing to clay
- Precambrian igneous rock (including some weathered material).

Table 6-1 Generalised Subsurface Conditions along Offshore Gas Trunkline Route

Zone Number	Approximate Water Depth (m)	General Material Description
1	20–48	SAND (SP): fine to medium grained, with up to 30% shell fragments that are up to 60 mm size. Trace of silt, soft coral with size up to approximately 95 mm encountered between 23 and 25 km. SILT and sand SILT encountered at two locations.
2	48–67	SAND, gravely SAND, silty SAND (SW–SM) and CEMENTED SAND: fine to coarse grained sand, well graded with up to 20% shells and shell fragments up to approximately 35 mm size, with some silt and occasional sandy gravel. Cemented sand and calcarenite particles recovered in some locations, relatively strong seabed material indicated at two locations by damage to gravity core sampler.
3	67–79	SAND, gravely SAND, Silty SAND (SW–SM): fine to coarse grained sand, well graded, with up to 90% shells and shell fragments up to approximately 60 mm size.
4	77–85	SAND, gravely SAND (SP–SW), CEMENTED SAND, CORAL and CALCARENITE: fine to coarse grained sand, well to poorly graded, with up to 80% shells and shell fragments up to approximately 60 mm size, indurated sand, live coral and calcarenite particles at most locations.
5	94–115	SAND (SP), silty SAND (SM) and clayey SAND (SC): fine to medium grained sand with up to 30% shells and shell fragments up to approximately 30 mm size.

Source: Adapted from Golder (2006). Preliminary interpretations based on limited depth sampling.

Spoil Disposal Grounds Seabed Characteristics

The seabed at the proposed deep water spoil ground 2B is comprised of soft sandy habitat (refer to **Section 7.9.5**). Similarly, the seabed within spoil ground A/B, which has been previously utilised for spoil disposal, comprises soft sandy sediments (refer to **Section 7.9.5**).

Sediment Chemistry

Sediment samples from the vicinity of the Pluto gas field were taken during the offshore marine survey conducted in December 2005, and analysed for the following trace metals: barium, cadmium, chromium, copper, iron, mercury, nickel, lead, tin, silicon, thorium, uranium, vanadium and zinc. Hydrocarbons were analysed as Total Petroleum Hydrocarbons (TPH) and Extractable Organic Matter (EOM) and a particle size distribution analysis was also performed.

The sediments were found to be clean when judged against the requirements of ANZECC/ARMCANZ (2000) for all trace metals and hydrocarbons. Detectable levels of total petroleum hydrocarbons were measured in most samples, however levels were very low. Despite a general trend of decreasing petroleum hydrocarbon levels with increasing depth, the maximum concentration of 7.93 ppm was in sediments collected from a water depth of 1000 m closest to the Pluto 1 well. Extractable Organic Matter (or biogenic hydrocarbons) was below 80 ppm in all samples. Detectable petroleum hydrocarbons probably represent background concentrations that may be attributable to natural oil seeps known to exist in the region.

Sediments ranged from fine sands to silts, and the patterns in sediment distribution were similar both within and outside the canyons. Sediment generally became finer with increasing water depth down to 600 m.

Past studies have rarely found contaminants in sediments of the Dampier Archipelago; this is considered to be attributable to the lack of riverine inputs and controls on discharges associated with current low levels of industrial development (MScience 2004). Sediments in Mermaid Sound are considered to be generally clean (in that they are below screening levels of National Ocean Disposal Guidelines for Dredged Material (NODGM) with TBT the only contaminant of concern. Tributyltin, which has been used as an anti-foulant on ships, is a compound acutely toxic to many species of marine animals as it inhibits growth. It leaches from treated surfaces, such as ship hulls, and is further introduced to the marine environment through paint flaking (Laughlin et al.1986). Tributyltin thus accumulates in sediments in areas of heavy shipping such as harbours and wharves. The elevated concentrations found in previous sampling programmes have been in the upper sediment layer in areas utilised by the shipping industry (IRCE 2003a; 2003b).

In January 2006, an extensive sediment survey of Mermaid Sound covering the proposed Pluto LNG Development channel and gas trunkline route (**Figure 6-12**) screened the upper 1 m of seabed for TBT. Overall the 95% Upper Confidence Limit of TBT for all areas was below screening level as stipulated by the NODGM, and the sediments are therefore considered acceptable for ocean disposal. Of the 98 sites screened only two sites contained TBT above detection levels (**Figure 6-12**) with values of 20 µg Sn/kg and 3.85 µg Sn/kg (normalised to 1% Total Organic Carbon). Both samples were taken from the upper 50 cm of seabed, with the lower 50 cm of the same sites containing no detectable TBT, indicating TBT contamination was confined to the upper layer of seabed. The sample containing 20 µg Sn/kg was one of three taken at the same location as part of a triplicate series for analysis of inter-sample variation. The other two samples in this triplicate series contained no detectable levels of TBT. This is not unusual given paint flakes from ships can cause highly localised elevated levels of TBT in sediments. Both sites containing detectable levels of TBT were in close proximity to an existing shipping channel.

A complete prohibition on the presence of TBT paints on ships by 1 January 2008 will likely see a continuing reduction of TBT levels in sediments in the Dampier Archipelago.

In the first quarter of 2006, a further 35 sediment samples were collected at 15 borehole locations from the lower seabed (that is, below 1 m) during a geotechnical survey undertaken by Woodside in Mermaid Sound (**Figure 6-12**). Sporadic traces of petroleum based hydrocarbons were found, with no detectable levels of any polyaromatic hydrocarbons listed by the NODGM. The sediments were also tested for metals, with levels of arsenic, chromium, nickel and silver found slightly above screening level in a few individual samples. However, the overall 95% Upper Confidence Limit of all hydrocarbons and metals was below the screening levels as set by the NOGDM and the sediment was therefore considered acceptable for ocean disposal. Based on the variance found in the dataset, further analysis showed the power of the 95% Upper Confidence Limits for all metals to be above 80% both when calculations were based on individual samples (35) or composite samples (one for each borehole). The 80% level is generally considered sufficient power for statistical analysis, indicating that 35 individual samples or 15 composite samples were sufficient for accurately describing the levels of metals in the sediments.

Analysis of particle size distribution from the January 2006 sediment survey (**Figure 6-12**) found sediments adjacent to Holden Point to be predominately sand (particle size of 0.06–2.0 mm). Further offshore within the proposed navigation channel the sediments were comprised of sand (particle size of 0.06–2.0 mm); silt (0.002–0.06 mm) and clay (≤0.002 mm).

6.2.5 Geology and Geomorphology

The basement rocks in the North West Shelf region are granitic and volcanic rocks of Precambrian age (2700–3300 million years old) and are overlain to the west by the Phanerozoic sediments (70–300 million years old) of the Canning Basin (Bird and Schwartz 1985).

The Pluto gas field is located within the Carnarvon Basin, which extends for over 1000 km along the north-western coastline between Geraldton and Karratha. The gas trunkline route is located within the Barrow and Dampier sub-basins of the Carnarvon Basin (Golder 2006). Along the coast of the North West Shelf, the Precambrian and Phanerozoic rocks are generally overlain by a thin covering of predominantly limestone sediments deposited in the last 65 million years. The limestone is often exposed to form pavements in the intertidal or sub-tidal zones off beaches and islands, as well as forming reefs (Bird and Schwartz 1985).

Some of the islands of the Dampier Archipelago are comprised of rocks of Precambrian origin and others are predominately limestone. The geology of Mermaid Sound is one of basalt rocks overlain by calcarenite, consolidated marine sediments and fine unconsolidated sediments.

6.3 Ecological Marine Environment

6.3.1 Benthic Primary Producers

Benthic biological productivity on the outer continental shelf and slope is low, and is a function of water depth and associated light attenuation, low nutrient availability, and the absence of hard substrates. Seafloor communities in deeper waters are relatively unproductive, and even with the relatively clear open ocean conditions in the area, light penetration to the sea bed at a depth of 100 m is generally insufficient for the development of plants (seagrasses and algae) and scleractinian (reef building) corals.

Intertidal and shallow subtidal habitats are extensive and well developed along the Pilbara coastline, and include mangroves, coral and rocky reefs, algae and ephemeral seagrass beds (**Figure 6-13**) (Wells and Walker 2003; CALM 2005). The Dampier Archipelago consists of 12 major islands and many smaller islands and has a high diversity of nearshore marine habitats where sediments change across the Shelf due to currents, waves and terrestrial inputs in coastal waters (CSIRO 2002). Similarly, water turbidity increases from the clear, oceanic waters offshore to relatively turbid waters inshore.

Mangroves

The geographical distribution of mangrove habitat is typically restricted to sheltered areas such as estuaries, tidal creeks and sheltered bays. Mangroves are recognised as being important habitats for feeding grounds and fish nurseries, as well as protecting coastal areas from erosion by stabilising sediments.

There are seven mangrove species recorded from the Dampier Archipelago and Pilbara coastal area (**Table 6-2**) (CALM 2002). The mangroves along the Pilbara coastline are arid zone mangroves, which are characterised by smaller tree size, relatively lower productivity and less species diversity than mangroves found in wet tropical areas (for example, the Northern Territory). These characteristics are due to the extreme water and salinity characteristics of the Pilbara's intertidal zone (EPA 2001). Of the seven species, the red mangrove (*Rhizophora stylosa*) and the grey or white mangrove (*Avicennia marina*) are the most common, and both of these species are found throughout northern Western Australia, Northern Territory, Queensland and northern New South Wales (Zann 2001).

Table 6-2 Mangroves Recorded in the Pilbara Region

Scientific Name	Common Name
Aegialitis annulata	Club mangrove
Aegiceras corniculatum	River mangrove
Avicennia marina	Grey mangrove/ white mangrove
Bruguiera exaristata	Ribbed-fruited orange mangrove
Ceriops tagal	Yellow-leaved spurred mangrove/ spurred mangrove
Osbornia octodonta	Myrtle mangrove
Rhizophora stylosa	Spotted-leaved red mangrove

Figure 6-9 Locations of ROV Surveys, Box Core Samples and Epibenthic Sled Tows and Photos of Seabed in the Vicinity of the Pluto Gas Field

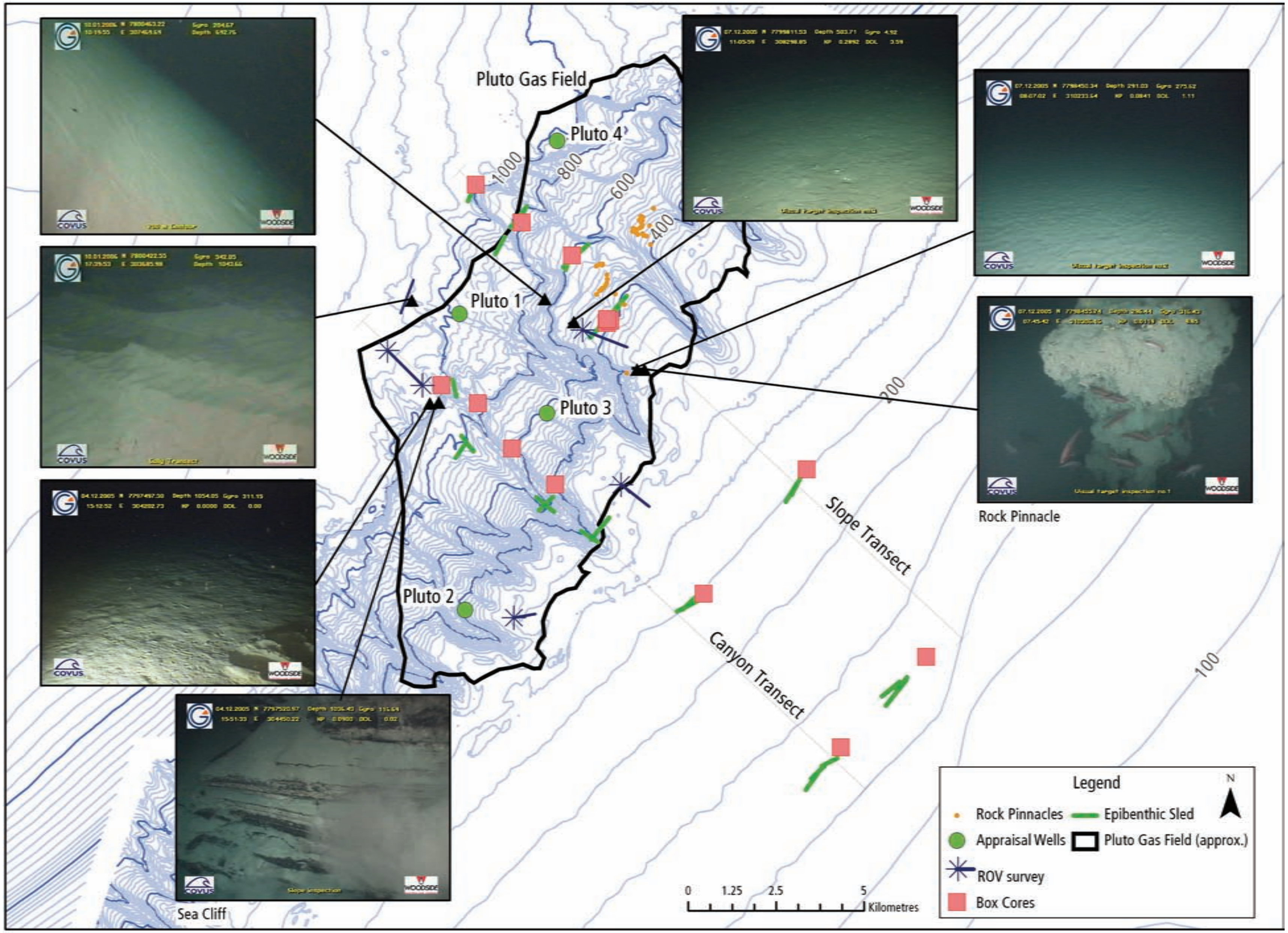


Figure 6-10 Seabed Features of the Platform Area

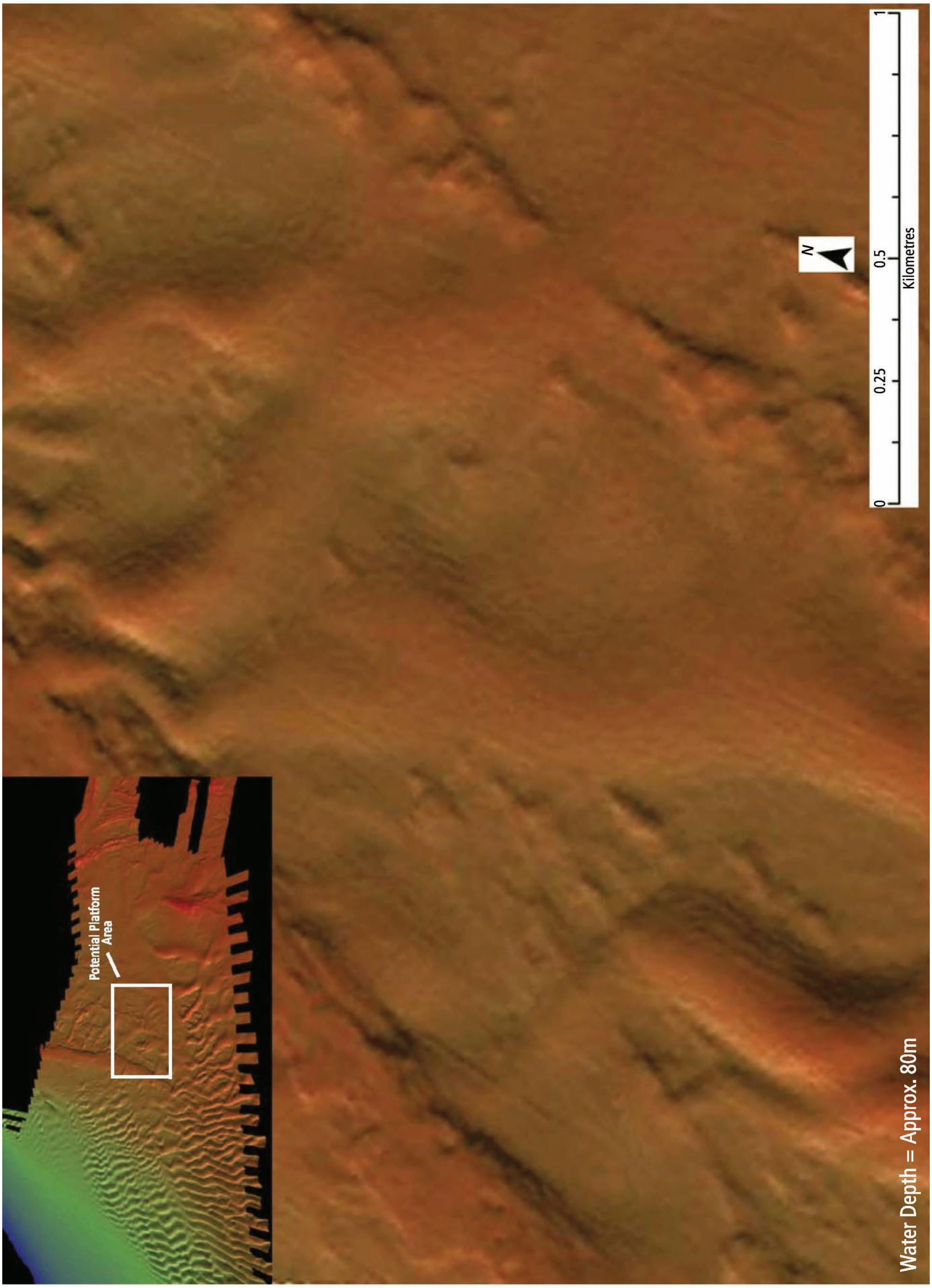


Figure 6-11 Seabed Characteristics along Gas Trunkline Route

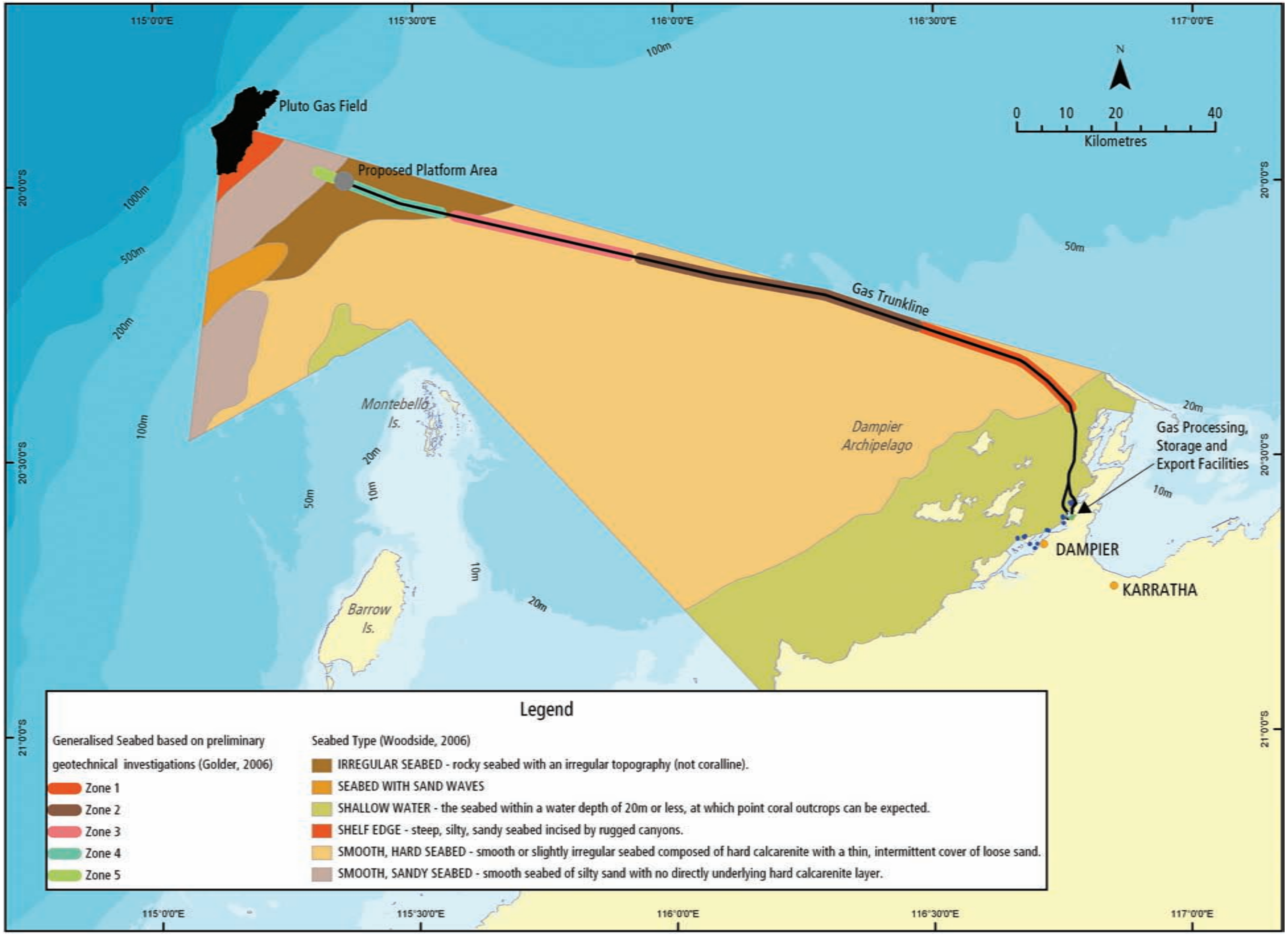


Figure 6-12 Sites Sampled during January 2006 Mermaid Sound Sediment Survey

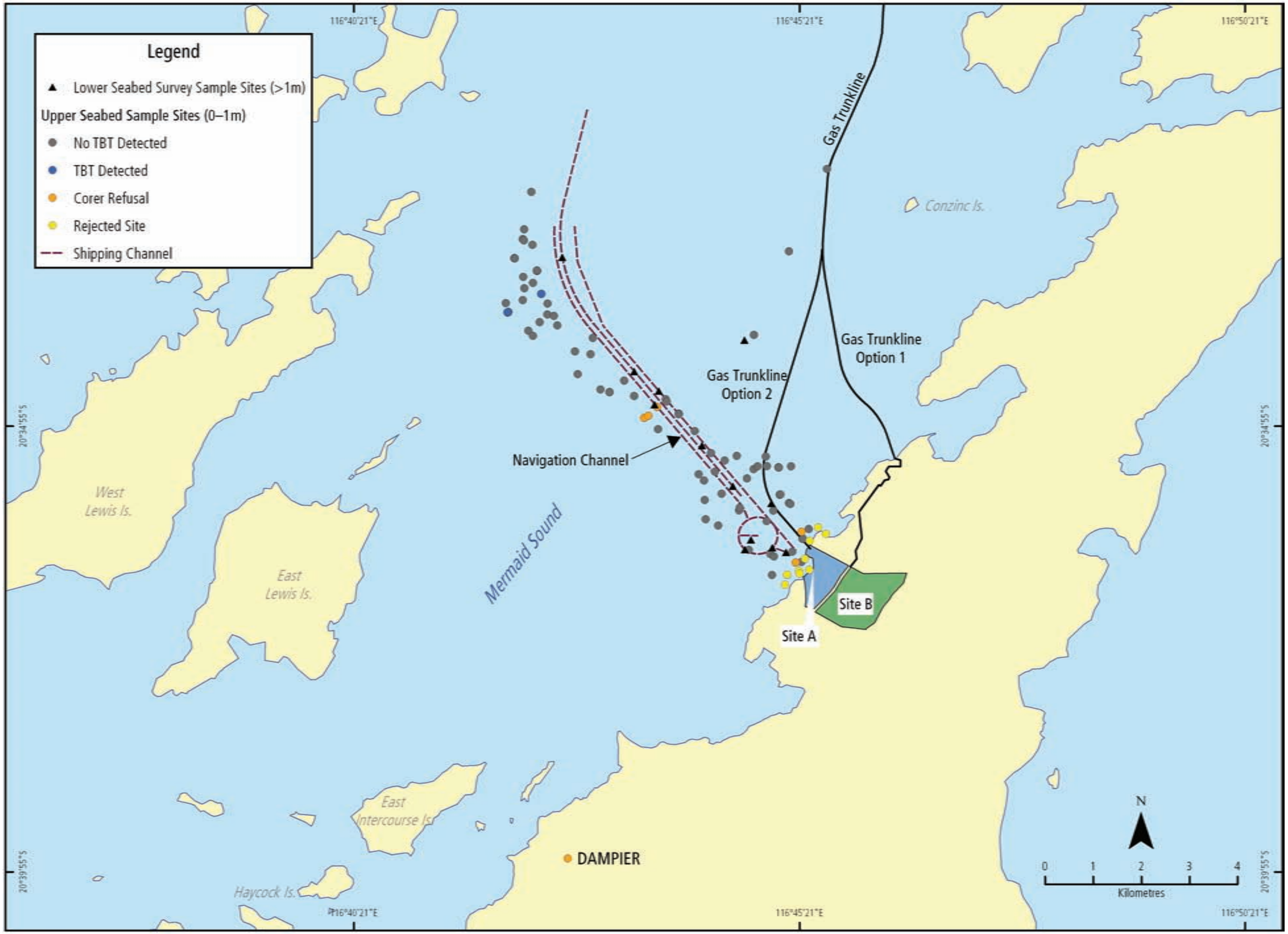
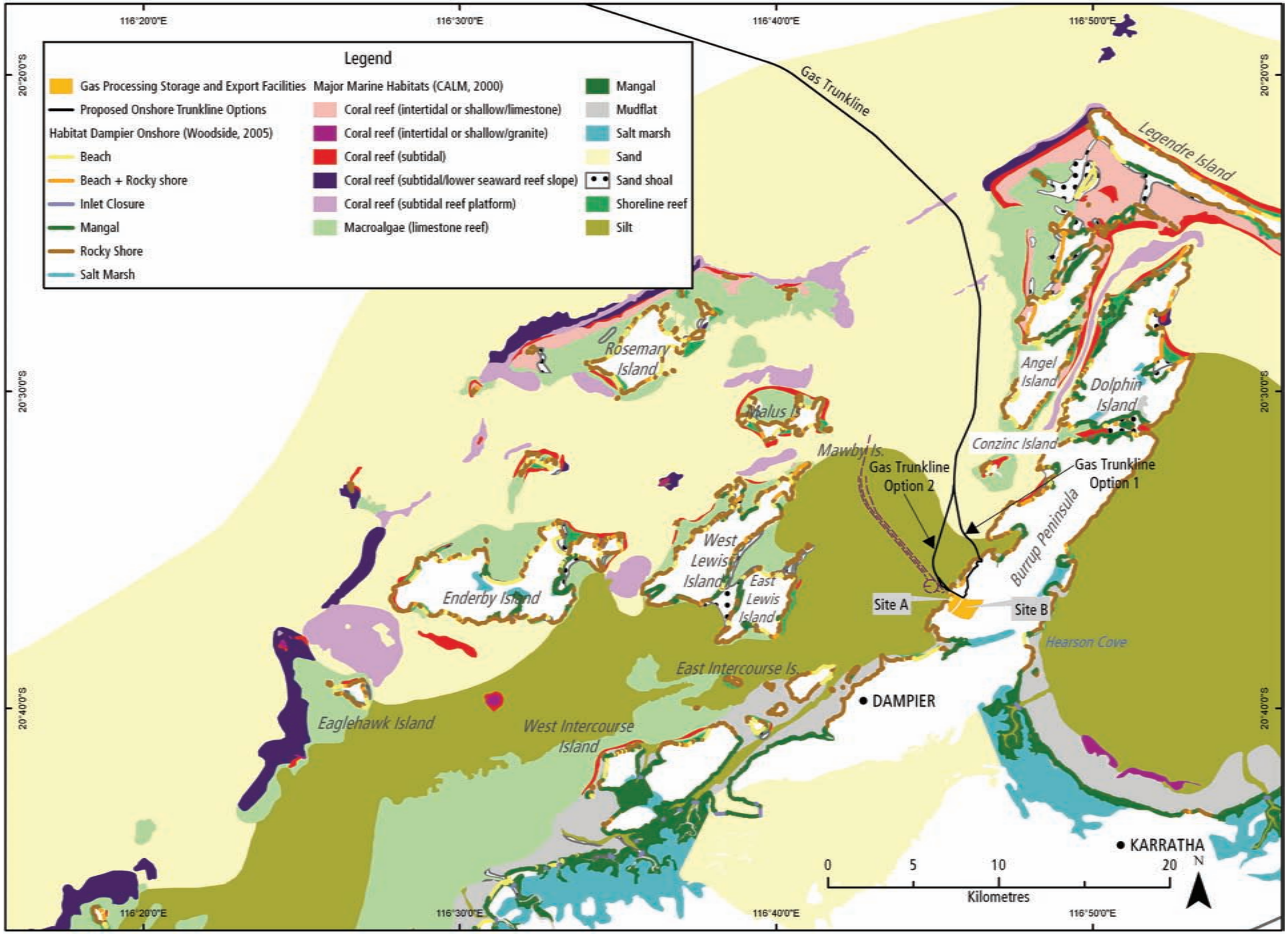


Figure 6-13 CALM Marine Habitat Map



Mangroves in the region are mainly found in muddy intertidal areas, although they can also be found growing on rocky or sandy substrates (Jones 2004). Within the Dampier Archipelago, well-established mangroves can be found at West Intercourse Island and to a lesser extent in Searipple Passage and in sheltered areas along the south-west shores of West Lewis and East Lewis Island. A tidal creek on Enderby Island also supports well-developed mangroves.

Much of the mainland Burrup Peninsula consists of exposed rocky shore that supports only small isolated mangrove stands, mainly of *Avicennia marina* (URS 2000). Mangroves are also found in bays and on intertidal sand or mud flats of the mainland and are particularly well developed at King Bay, Withnell Bay, Nickol Bay, Conzinc Bay, the Maitland River mouth and on the tidal flats at Regnard Bay (CALM 2002 and 2005). **Figure 6-14** shows the distribution of mangroves throughout the Burrup Peninsula and the Dampier Archipelago and indicates Mangrove Management Areas that contain mangroves considered to be of very high conservation value by the EPA (2001). The remaining mangroves in the area, although not 'regionally significant', are also regarded as important and considered to be of high conservation value (EPA 2001). Extensive losses of mangroves were associated with clearing for the development of Dampier Salt ponds.

Coral

The Pilbara region contains an assortment of substrates and oceanographic conditions which support a variety of coral species, including exposed reef with high wave action and sheltered areas with high sediment deposition. The abundance of corals in the region varies spatially with clearer waters in offshore areas having higher coral density and diversity than that of high turbid nearshore areas. The nearshore marine environment does however, have relatively high species counts for an inshore reef system (Blakeway and Radford 2005). Both scleractinian and non-scleractinian corals are found throughout the Dampier Archipelago, including a total of 229 species from 57 hermatypic coral genera (Griffith 2004), representing a large proportion of the 318 hermatypic species from 70 genera known to occur in Western Australia (URS 2004a).

Investigations into the reproductive ecology of corals in the Dampier Archipelago have been undertaken by several researches (Simpson 1985; 1987, Heyward et al. 2000, Stoddart and Gilmore 2005). The majority of coral species are broadcast spawners, meaning that they release gametes into the water column. Broadcast spawners in the Dampier Archipelago have two main reproductive events which occur seven to ten nights after the full moon between March and April and a less pronounced spawning event between October and November (Simpson 1988). Similar spawning events near Barrow Island (RPS BBG 2005) and at Ningaloo Reef (AIMS 2004) have been associated with mass coral mortality due to anoxic conditions resulting from respiration and then decomposition of very large quantities of coral larvae. No record of similar mass coral mortality events has been found for the Dampier Archipelago, possibly due to lower coral coverage and/or higher rates of mixing through the water column.

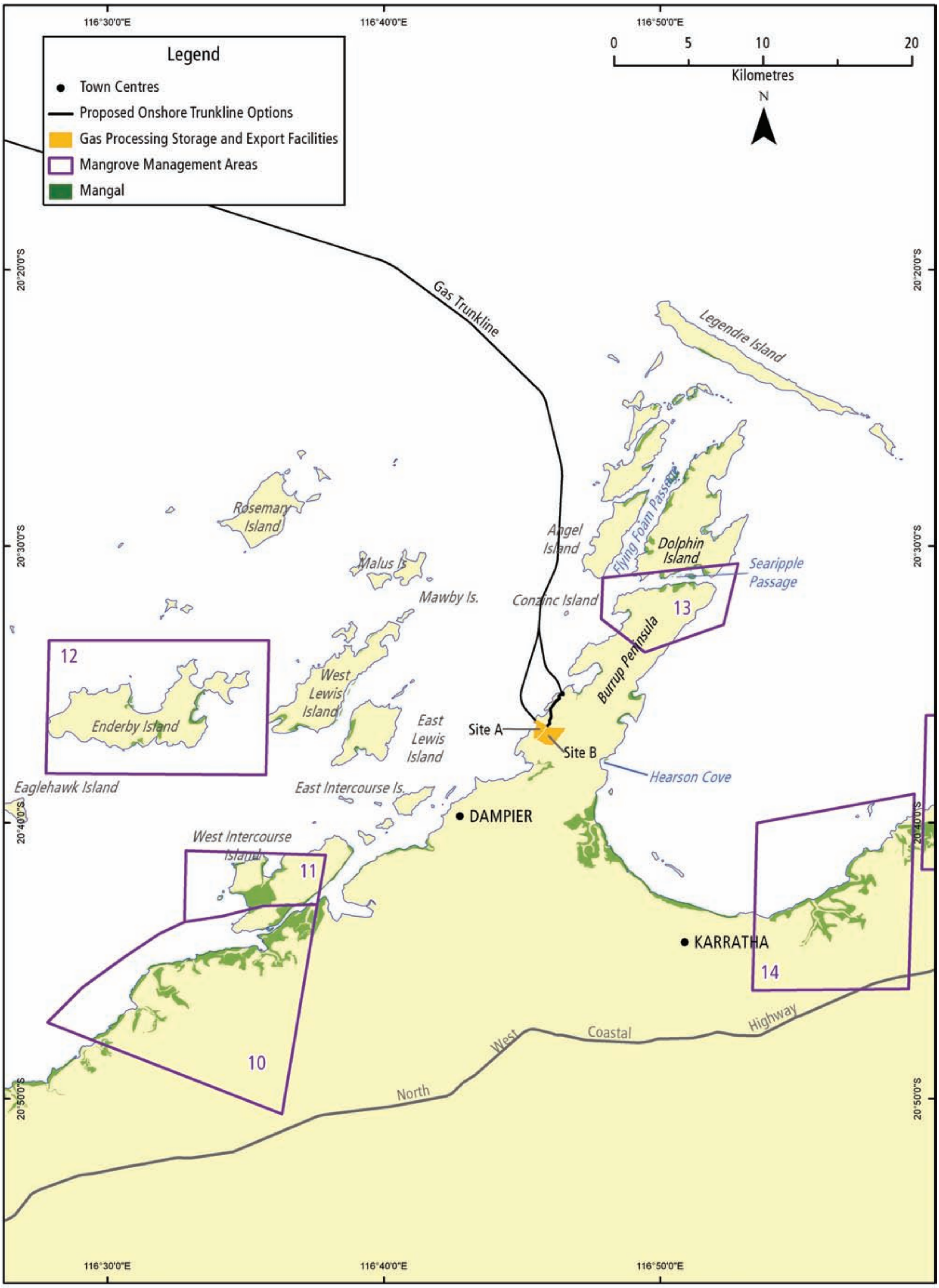
The most diverse coral assemblages of the Dampier Archipelago are on the seaward slopes of outer islands such as Delambre Island, Legendre Island, Rosemary Island and Kendrew Island (Jones 2004; CALM 2005). Areas supporting a broad variety of corals are also found at Hamersley Shoal, Sailfish Reef and north-west Enderby Island.

The coral communities along the mainland Burrup Peninsula coast show little evidence of reef development; rather they grow by encrusting solid substrata such as Precambrian rock (URS 2004a; Jones 2004). Coral reefs have been recorded in the vicinity of King Bay, between Phillip Point and the Dampier Public Wharf; however, water conditions in this area are extremely turbid and the reef is considered to be patchy (Water Corporation 2000). URS (2003) has recorded various species of coral along the western coast of the Burrup Peninsula, with the most dominant genera being *Favities*, *Favia*, *Platygyra*, *Goniastrea* and *Caulastrea*, as well as *Turbinaria* colonies. Other common corals recorded include *Porites*, *Pavona*, *Acropora*, *Lobophyllia*, *Symphyllia*, *Goniopora*, *Montipora* and *Pectinia* species (URS 2003). Corals are sensitive to natural and anthropogenic influences, and can be damaged by weather, predators, dredging, fishing and anchoring. There are also various reported incidences of corals being damaged by cyclones, including significant coral declines at Sailfish Reef and reefs off Kendrew Island following cyclonic wave damage in February 1975, as well as declines in coral cover along Mermaid Sound following cyclones Ilona in 1988 and Orson in 1989 (CALM 2005).

Coral monitoring at the beach west of Site A (CHEMMS 1) and the northern corner of Site A (CHEMMS 2) has been undertaken as part of broader chemical and biological monitoring of the intertidal and subtidal environment near the NWSV's existing port facilities in Mermaid Sound (URS 2004). Monitoring has been undertaken at nine sites, with the beach west of Site A (CHEMMS 1) being the most southern site and Conzinc Bay (CHEMMS 7) being the most northern. Coral monitoring comprises video-based surveillance and has been undertaken from 1995 to 1999 and in 2004. The monitoring has shown some physical loss of small *Acropora* colonies at CHEMMS 1, although it was considered likely that no net loss of coral occurred because of replacement by coral regrowth (URS 2004). CHEMMS 2 also demonstrated mortality of *Acropora* colonies; however, there was no detectable net change in coral cover, probably as a result of growth of *Acropora* and *Turbinaria* colonies counterbalancing the loss (URS 2004).

Rock pinnacles found in 300–500 m of water in the Pluto gas field appear to biogenic in origin, having been created by a deep water coral, and are discussed further in **Section 6.3.3**.

Figure 6-14 Mangroves and Mangrove Management Areas in the Vicinity of the Pluto LNG Development



Seagrass

Like macroalgae, seagrasses are dependant upon light as a source of energy. They are also dependent on suitable sea temperatures and sea conditions, and are generally found in coastal waters at depths of 2 m to 10 m, although they have been recorded at 50 m in some Australian waters (DEH 2005a). It is highly unlikely that seagrasses are present in offshore areas of the region beyond approximately 50 m depth, mainly due to light attenuation.

Seagrasses in the Dampier Archipelago are generally sparse, occurring in low abundance on shallow sandy sediments in sheltered areas such as flats and larger bays (CALM 2005; Jones 2004). Surveys in the region have identified nine species, these being:

- *Cymodocea angustata*
- *Enhalus acoroides*
- *Halophila decipiens*
- *Halophila minor*
- *Halophila ovalis*
- *Halophila spinulosa*
- *Halodule uninervis*
- *Thalassia hemprichii*
- *Syringodium isoetifolium.*

The most significant areas of seagrass in the Dampier Archipelago are found between Keast and Legendre Islands to the north of the Burrup Peninsula, and between West Intercourse Island and Cape Preston. Minor seagrass meadows are also found within macroalgal meadows in shallow sand areas such as West Conzinc Island (URS 2000) and Withnell Bay (Bertolino 2006). Recorded occurrences of *Halophila* species in the Dampier Archipelago fluctuate depending on a variety of factors such as salinity, success of seed set and colonisation, temperature and grazing by dugongs.

The nearshore survey of the proposed shipping channel adjacent to Site A did not record any occurrences of seagrass.

Seaweed and Algal Turfs

Macroalgae, or seaweeds, generally require a hard substrate, sufficient sunlight and water clarity and so are generally limited to shallow water. In nearshore areas, macroalgae are most commonly found on shallow limestone pavements located throughout the Dampier Archipelago and along coastal areas of the Pilbara according to the CALM habitat map (**Figure 6-13**). Large expanses of macroalgae are prevalent along the seaward side of West Intercourse Island, extending south-west along the coast to Cape Preston and beyond. Large macroalgal platforms are also evident at Rosemary Island, Nelson Rocks, Legendre Island, West Lewis and East Lewis Islands, Enderby Island, Gidley Island, Eaglehawk Island, Malus Island and Angel Island. These platforms generally occur on the northern and western sides of the islands.

The most abundant group of algae in the region is brown algae, or Phaeophyceae. In particular, species from the genus *Sargassum*, *Dictyopteris* and *Padina* are very common. The most common species of green algae (Chlorophyta) in the Dampier Archipelago include *Caulerpa* species and calcareous *Halimeda* species (CALM 2005; Jones 2004). A variety of red algae (Rhodophyta) are found in the Dampier Archipelago including corallines (for example *Amphiroa* species), calcified red algae (for example, *Galaxaura* and *Patenocarpus* species) and algal turf (Jones 2004).

The nearshore marine survey of the proposed shipping channel into Site A recorded soft sediments only, with isolated and very sparse sponges, soft corals and macroalgae. The survey also identified seapens, marcroalgae and seawhips in isolated areas of spoil ground 2B, albeit in very limited quantities.

6.3.2 Plankton

Phytoplankton groups in the waters of the North West Shelf include diatoms, coccolithophorids and dinoflagellates. Studies indicate that the standing crop of phytoplankton on the North West Shelf is not particularly high (approximately 20–40 mg Chl-a/m^3) and is nitrogen limited (Herzfeld et al. 2003). Surface waters of the North West Shelf contain very little nitrate so that at most times of year the bulk of the phytoplankton standing crop on the North West Shelf lies well beneath the surface, either at the base of the thermocline or in the bottom mixed layer adjacent to the seafloor where high concentrations of nitrates exist (refer to **Section 6.2.2** for details on the North West Shelf thermocline).

While surface waters of the North West Shelf are oligotrophic, the mixing and upwelling of deeper offshore waters near the Shelf create localised intermittent fluxes of nutrient rich water and, in turn, enhanced productivity in the surface mixed layer (refer to **Section 6.2.3** for details on nutrients). Areas of enhanced production are also observed at the interface between stable waters warmed by solar heating and unstable waters mixed by tidal turbulence, but such fronts are rarely found seaward of the 40 m isobath (Heyward et al. 2000).

There is limited seasonal variability in the observed distribution of phytoplankton with the little variation that does occur being a more vertical concentration in summer and more dispersion during winter (Herzfeld et al. 2003). This unexpectedly low variation may be attributed to the Leeuwin Current minimising the intrusion of high-nitrate slope water onto the Shelf in winter when mixing would normally result in increased productivity. Summer productivity is naturally low and as a result seasonal variation in the standing crop of phytoplankton is limited.

Intensive studies (Pollard and Moriarty 1984; Furnas and Mitchell 1998) show that very rapid recycling can occur in phytoplankton on the North West Shelf. Planktonic bacteria are very important in carbon cycling and the bacteria of the mudflats may be a major source of nutrients to the inshore ecosystem (Heyward et al. 2000).

During the warmer months, extensive blooms of *Trichodesmium* occur throughout the region, including the waters of the Dampier Archipelago, but its role in nutrient cycling and the trophic system is not known (Creagh 1985), although it might contribute significantly to the nitrogen budget. There have been no known deleterious water quality impacts caused by toxic algal blooms in the region (Heyward et al. 2000).

Zooplankton feed on phytoplankton and provide an important food source to larger animals such as whales, fish and crustaceans. Large inter-annual changes in macrozooplankton assemblages have been reported on the North West Shelf and have been attributed to variations in upwelling associated with internal waves (Meekan et al. 2003). In addition to the species listed in **Table 6-3**, a total of 22 zooplankton species and 45 other planktonic taxa, including crustaceans, molluscs, polychaete worms, arrow worms, sea squirts and coelenterates, have been introduced into Dampier Archipelago via vessel ballast water (Jones 2001).

6.3.3 Marine Invertebrates

Sampling of marine invertebrates offshore of the Angel gas field (approximately 150 km north-east of the Pluto gas field), in water depths of approximately 80 m and of broadly similar habitat to the riser platform location and the mid section of the proposed gas trunkline route, recorded 2979 individual animals from 12 phyla and 251 nominal species (BBG 2002). The most abundant infauna recorded were polychaete worms from the phylum Annelida, which comprised 40.5% of the species collected. Crustaceans (Phylum Crustacea) were also common, comprising 25.5% of the total species collected (BBG 2002). Other marine invertebrates recorded at the Angel gas field include bivalve molluscs, sea cucumbers, brittle stars, sponges, jellyfish, ribbon worms and flatworms.

The nearshore Dampier Archipelago supports an abundant and diverse group of tropical invertebrate species due to the wide variety of suitable habitats. Over 2226 species of marine invertebrates have been recorded in the Archipelago, including 1227 molluscs, 438 crustaceans, 275 sponges and 286 echinoderms (CALM 2005).

According to Jones (2001) a total of six marine macrobiota have been confirmed as being introduced into the Dampier Region (**Table 6-3**). Many of the introduced species have been recorded as one or a few individuals on one or a few occasions.

An offshore survey conducted in the Pluto gas field found that the majority of the field seabed was comprised of uncontaminated soft sediments supporting a typically sparse but highly diverse deep water fauna (SKM 2006c). Infauna was comprised predominately of polychaetes and epifauna/demersal fauna comprised of solitary cnidarians, malacostracan crustaceans, fish and sponges typical of the region (SKM 2006c). Several of the species observed had not been recorded previously in Australia, Western Australia or the North West Shelf region. However, taxonomic experts from the Western Australia Museum attributed this to the limited number of previous studies of the continental slope rather than to the rarity of the fauna (SKM 2006c).

The distribution and abundance of epifauna was found to be related to depth, with distinct differences on the Shelf and slope. Seventy percent of the solitary corals collected occurred in those samples collected from the 200 m water depth sample sites, while crustaceans were most abundant at sites of 400 m depth. The majority of the 50 crustacean species identified belonged to the Order Decapoda (48 decapods and two barnacles, Order Pedunculata). Sponges were most abundant in the deeper stations (600 m and 800 m) while ascidians were common in 150 m water depths where one unidentified species was particularly abundant. Most molluscs occurred in depths of between 150 m and 600 m. Most of the 45 mollusc species had been previously recorded from western and northern Australian waters, although some of the specimens in the collection belong to species that have been rarely collected, for example, *Amoria diamantina*. Molluscs were represented by 27 families, of which four were cephalopods, three were bivalves and the remaining 47 species were gastropods.

No epifauna was observed on areas of exposed rock on the sea cliffs in about 1000 m water depth (**Section 6.2.4**). Where the seabed gradients were less steep, sediments accumulated and large anemones and batfish were observed. However, both the abundance and diversity of epifauna was limited in these rock areas, compared to the sedimentary seabed located above and below the area of sea cliffs.

Offshore surveys and preliminary geotechnical data of the Pluto gas field indicate the presence of a small rock pinnacle field located in water depths of approximately 300 m (SKM 2006c). The pinnacles have been constructed by the deep water coral *Lophelia* but do not appear to have joined together

Table 6-3 Marine Organisms Introduced into the Dampier Region

Species Name	Family	Method of Introduction	Possible Origin of Introduction
Botrylloides leachi	Ascideacae (Sea squirt)	Unknown	Europe, Atlantic
Balanus amphitrite	Crustacea (Barnacle)	Hull fouling	Cosmopolitan in tropical, subtropical and temperate waters. Species is a common fouler throughout Western Australia.
Balanus cirratus	Crustacea (Barnacle)	Hull fouling	Indo-west Pacific
Balanus trigonus	Crustacea (Barnacle)	Hull fouling	Cosmopolitan in tropical and warm temperate waters
Megabalanus rosa	Crustacea (Barnacle)	Hull fouling	Japan, China, Taiwan
Megabalanus tintinnabulum	Crustacea (Barnacle)	Hull fouling	Cosmopolitan

Source: Adapted from Jones (2001)

into a more extensive reef as the ROV used observed a muddy seafloor between adjacent pinnacles. Shrimps, anemones and hydroids were observed living on these pinnacles. Many tens of fish were observed gathered around these pinnacles; most probably belonging to either the Glaucosomidae or Pricanthidae families. A few larger fish were evident, probably a deep water snapper, but definitive identification could not be made from the ROV footage. Deep water, reef building corals occur along the edges of continental shelves and around offshore submarine banks and seamounts in all of the world's seas and oceans. The distribution of these corals is still poorly known, but with the increasing exploration of the deep sea, more occurrences are being discovered. Deep water corals can grow without light and are not considered to be benthic primary producers as they do not rely on symbiotic algae (zooxanthellae) for survival (SKM 2006c). The discovery of deep water coral at the Pluto gas field appears to be the first record of such coral in the vicinity of the North West Shelf; however, this may reflect the lack of deep water exploration rather than the rarity of deep water coral per se.

Filter Feeder Communities

The Dampier Archipelago contains a species-rich sponge fauna, with 275 sponge species recorded, of which approximately 20% are presently known to be limited to Western Australia and are likely to be endemic (Fromont 2003). While extensive surveys of the Western Australian coastline are limited, there is data to suggest that some sponge species have limited distributions and Fromont (2003) suggests that the high level of endemism may be the result of a short larval phase and limited dispersal.

Surveys conducted by Fromont (2004) found that the highest diversity of sponges in the Dampier Archipelago occurred in sponge communities, which were 'either low relief or pavement habitats, often with a sediment layer and always with a high diversity of sponges and sessile coelenterates such as gorgonians and soft corals. These environments had strong tidal currents.' Sponge communities have been observed at the eastern end of Flying Foam Passage, at the western end of Mermaid Strait and between Enderby and West Lewis Islands (Jones 2004).

Monitoring undertaken for the NWSV second trunkline project also recorded a sponge community habitat between Angel and Conzinc Island, near the western end of Flying Foam Passage (IRCE 2004a).

6.3.4 Fish

The North West Shelf supports a diverse assemblage of fish, particularly in shallow waters near the Dampier Archipelago. Pelagic species in offshore waters of the North West Shelf include marlin (*Makaira* spp.), sailfish (*Istiophorus* spp.), Spanish mackerel (*Scomberomorus* spp.), golden trevally (*Gnathanodon* spp.), sharks (*Carcharhinus* spp.) and turrum (*Caranx* spp.). Some of these species are the focus of game-fishing in the area (CALM 2005). Whale sharks (*Rhincodon* typus) aggregate annually at Ningaloo Reef, some 100 km south-west of the Development area, with the main aggregation period being late March to July. It is thought that this aggregation occurs in response to local food availability.

Coastal waters support dense schools of baitfish such as herring (*Herkolotsichthys* spp.), sardine (*Sardinella* spp.) and anchovy (*Stolephorus* spp.), which in turn support pelagic fish. The baitfish also support the bulk of the shearwater and tern species (**Section 6.3.7**).

The fish fauna of the outer islands of the Dampier Archipelago are dominated by coral reef fishes, while mangrove and silty bottom dwellers comprise the majority of the fish assemblages in the inner areas of the Archipelago, close to shore. Areas in the northern perimeter of the Archipelago, near to Legendre Island, contain the most diverse fish species (Hutchins 2004). These clearer, more offshore areas, may be under the direct influence of the Leeuwin Current, and may experience high deposition of propagules from upstream locations such as the Rowley Shoals. Closer to shore, where waters are more turbid, fish diversity is lower. The fish fauna of the Dampier Archipelago is closely related to that of the more offshore Montebello Islands, but is significantly less diverse than fish communities further south at Ningaloo Reef.

Hutchins (2004) studied the shallow-water fish fauna of the Archipelago (to a depth of 30 m) and found it comprised a total of 650 species and featured a prominent component of coral reef species (465) and to a lesser extent mangrove species (116). The fish fauna, part of the tropical inshore fauna that extends from Shark Bay to Queensland, also comprises smaller numbers of soft bottom inhabitants (106 species) and a relatively low number of pelagic species (67). A separate study by Hutchins (2003), which also included species trawled and dredged to a depth of 45 m, identified 735 species of fish fauna in the Dampier Archipelago area. Larger species that attract divers and recreational and commercial fishers include coral trout (*Plectropomus* spp.), tusk fish (*Cheorodon* spp.), rock cod, large potato cods (*Epinephelus tukula*) and manta rays (*Manta birostris*).

A number of pipefish, pipehorses and sea horses (of the family Sygnathidae) species are found in the vicinity of the Dampier Archipelago and are discussed in further detail in **Section 6.3.8**.

6.3.5 Marine Reptiles

Sea turtles are found worldwide in tropical, subtropical and warm temperate waters. The green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), flatback turtle (*Natator depressus*) and loggerhead turtle (*Caretta caretta*) occur in the Pluto LNG Development area and all are recorded as nesting on sandy beaches found in the region (refer to **Figure 6-15**). The conservation status of these species is detailed in **Section 6.3.8**.

The Dampier Archipelago region also has important sea turtle aggregation sites, particularly in the waters surrounding islands such as Rosemary Island, Malus Island, Enderby Island, Eaglehawk Island, Legendre Island and Delambre Island (CALM 2005).

The green turtle breeds in summer in Western Australia, and is known to have major nesting rookeries on Rosemary Island, as well as on the north-east coast of Legendre Island and the western and eastern shores of Delambre Island. Principal rookeries are also found regionally at the Lacepede Islands, Montebello Islands, Barrow Island, Lowendal Islands and Browse Island. A number of smaller nesting sites can also be found on the mainland between the Ningaloo and Kimberley coasts.

Western Australia is a significant location for hawksbill turtles, with nesting occurring throughout the year, peaking between October to January (DEH 2006). Hawksbill turtles mainly nest on Rosemary Island in the Dampier Archipelago, particularly on the north-western side of the Island, and it is believed that Rosemary Island may support up to 1000 nesting females annually (Limpus 2004). Nesting also occurs on the Montebello Islands and Lowendal islands.

Australia has the only recorded nesting populations of flatback turtles. In Western Australia, they have been recorded breeding from Exmouth north to Cape Domett on the Kimberley Coast; however, little information is available regarding these populations (Limpus 2004). Breeding in the Pilbara region peaks in summer and significant rookeries are known to occur on Barrow Island, Montebello Islands, Thevenard Island, Lowendal Islands and islands of the Dampier Archipelago and off the Kimberley coast over 100 km from the Pluto gas field. Minor rookeries are widespread along the mainland beaches of Western Australia from Mundabullangana on the Pilbara coast north to Broome. Flatback turtles are known to feed throughout Australian continental shelf waters (Limpus 2004).

Recent data indicates that internesting flatback females appear to spend time commuting away from Barrow Island to areas close to the adjacent mainland coast, returning several times to Barrow Island to nest during the season. Migratory data from some flatback females indicates that some females vacate the Barrow Island area altogether outside of the nesting season to locations near the Pilbara and Kimberley mainland. Green and hawksbill turtles may also undertake similar migrations and have been observed tracking through or skirting around the Dampier Archipelago on their way north (Seaturtle.org 2006; K Pendoley [Pendoley Environmental] 2006 pers comm. September).

Loggerhead turtles are known to nest from Shark Bay to the southern North West Shelf (Limpus 2004). Nesting activity is limited within the Development area, but can occur on the beaches of the Barrow/Montebello Islands and as far north as some islands of the Dampier Archipelago (CALM 2002). Basking loggerhead turtles have been recorded on islands of the North West Cape and Dampier Archipelago.

Although listed as occurring in the Development area (DEH 2006), the leatherback turtle (*Dermochelys coriaceaa*) is considered unlikely to occur (Limpus 2004).

Evidence of low density flatback turtle and possibly green turtle nesting attempts were recorded on the beach west of Site A during a survey in January 2006 (Pendoley 2006). Low density nesting efforts have previously been recorded on this beach in December 2005. In a regional context, the beach west of Site A supports a very minor sea turtle rookery (Pendoley 2006).

No sea turtle nesting is likely to occur at the beach north of the NWSV Karratha Gas Plant where the trunkline crosses for Option 1 as this beach is completely inundated during high tides, making it unsuitable for turtle nesting.

Greer (2004) and Guinea et al. (2004) recorded twelve species of seasnake in the Pilbara region, with the olive seasnake (*Aipysurus laevis*) being the most common. Most of the recorded seasnakes belong to the family Hydrophiidae (true seasnakes) and inhabit a variety of environments. The horned seasnake (*Acalyptophis peronii*) prefers sandy substrates, whilst species such as Dubois' seasnake (*Aipysurus duboisii*) and the olive seasnake inhabit coral reefs (Greer 2004; Guinea et al. 2004). The black-ringed seasnake (*Hyderelaps darwiniensis*) is found in mangroves and mudflats, while other species are found in turbid waters and waters over soft bottoms such as mud, including the spine-tailed seasnake (*Aipysurus eydouxii*), olive-headed seasnake (*Disteira major*) and Stoke's seasnake (*Astrotia stokesii*) (Greer 2004; Guinea et al. 2004).

6.3.6 Marine Mammals

Dugongs

Dugongs (*Dugong dugon*) are associated with tropical and sub-tropical coastal waters, and in particular shallow, protected waters such as sheltered bays, mangrove channels and in the lee of large inshore islands (UNEP 2002). Dugongs are herbivores that feed on seagrass. The dugong's reproductive cycle is sensitive to food availability; with breeding delayed if sufficient food is not available (UNEP 2002).

The distribution of dugong in the Pilbara region is widespread, including Barrow Island and the Montebello Islands, the Dampier Archipelago and the mainland coastal waters. They have been recorded near various islands including Rosemary Island, East Lewis Island, West Lewis Island, Keast Island, Legendre Island and Little Rocky Island (CALM 2005; URS 2000). Dugongs have also been sighted in shallow, sheltered bays of the Burrup Peninsula and mainland such as Regnard Bay and Nickol Bay (CALM 2005), and on the seaward side of Hamersley Shoal at the entrance to Mermaid Sound (J Stoddart [MScience] 2006 pers comm. May). **Figure 6-16** illustrates dugong habitat in the vicinity of the Development area.

Dolphins and Whales

A number of dolphin and whale species have been observed in the Pilbara region. These are summarised in **Table 6-4**. Submarine canyon systems in the field may represent feeding grounds for pygmy blue whales (*Balaenoptera musculus brevicauda*), sperm whales (*Physeter macrocephalus*) and beaked whales (C Jenner [Managing Director, Centre for Whale Research] 2005 pers comm.17 November). Blue whales (*Balaenoptera musculus*) were recorded in the vicinity of the Pluto gas field by a noise logger during December 2005.

Humpback Whale Migration

The most significant aspect of dolphin and whale distribution within the Development area is the migration of breeding humpback whales.

Humpback whales (*Megaptera novaeangliae*) migrate annually from feeding grounds in the Antarctic to breeding grounds in Camden Sound in the Kimberley region of Western Australia (Jenner et al. 2001). The migratory path lies within the Australian continental shelf, and major resting areas along the way have been identified at Exmouth Gulf, Shark Bay and Geographe Bay (Jenner et al. 2001; DEH 2005c).

Overall, humpback whale migration along the Western Australian coast spans a number of months. Whales migrating north from Antarctica have been recorded reaching the southern Australian coast as early as April, most whales reach Camden Sound by August, and whales heading south to Antarctica have been recorded along the southern coast of Western Australia between October and November. Migration times vary annually depending on various factors including the availability of food, climate and ocean conditions.

Data collected from boat surveys at the Dampier Archipelago and from helicopter sightings by pilots travelling to and from oil and gas facilities on the North West Shelf suggest that the northern migratory path through the Dampier region is different to the southern migratory path in a number of respects:

- The northern path is generally further offshore, more widespread and less distinct.
- Humpback whales migrating north through the Development area may extend outward to the edge of the continental shelf, up to 70 nm from the coast.
- The majority of whales migrating south tend to stay closer inshore, passing within 10 nm of the coast, although a small proportion of the southwards migrating whale population does travel south via an offshore route (although not as far offshore as the northern path).
- Peak northern migration past the Dampier Archipelago is approximately between the last week of July and the first week of August.
- Peak southern migration through the Dampier Archipelago is around the last week in August and the first week in September (DEH 2005c; Jenner et al. 2001; Jenner and Jenner 1991).

Humpback whale northern migration routes intersect the Pluto LNG Development area through two main paths as shown in **Figure 6-17**. The southern most path intersects the proposed gas trunkline route approximately 100 km from shore, while further north the other migration path intersects the proposed platform area. Southward migration routes intersect the proposed gas trunkline route at a number of positions within and seaward of the Dampier Archipelago, and include a significant female and calf resting area within Mermaid Sound (CALM 2005). Adult humpback whales and their young also frequent the Archipelago on their southern migration in early spring (CALM 2005). A southward migration path also intersects the proposed gas trunkline route approximately 125 km from shore (**Figure 6-17**).

Figure 6-15 Sea Turtle Nesting Sites in the Dampier Archipelago

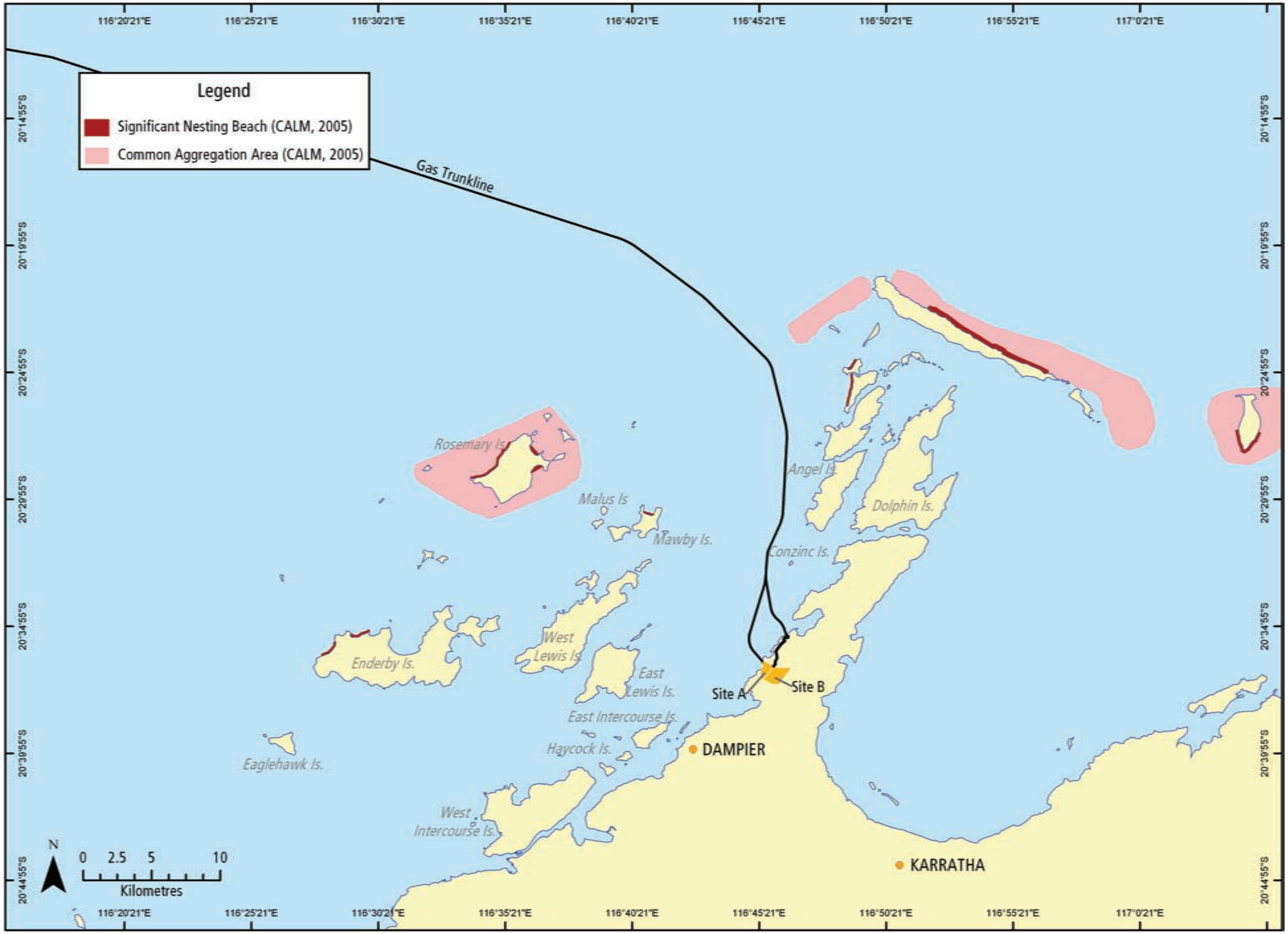


Figure 6-16 Dugong Habitat Distribution in the Vicinity of the Pluto LNG Development

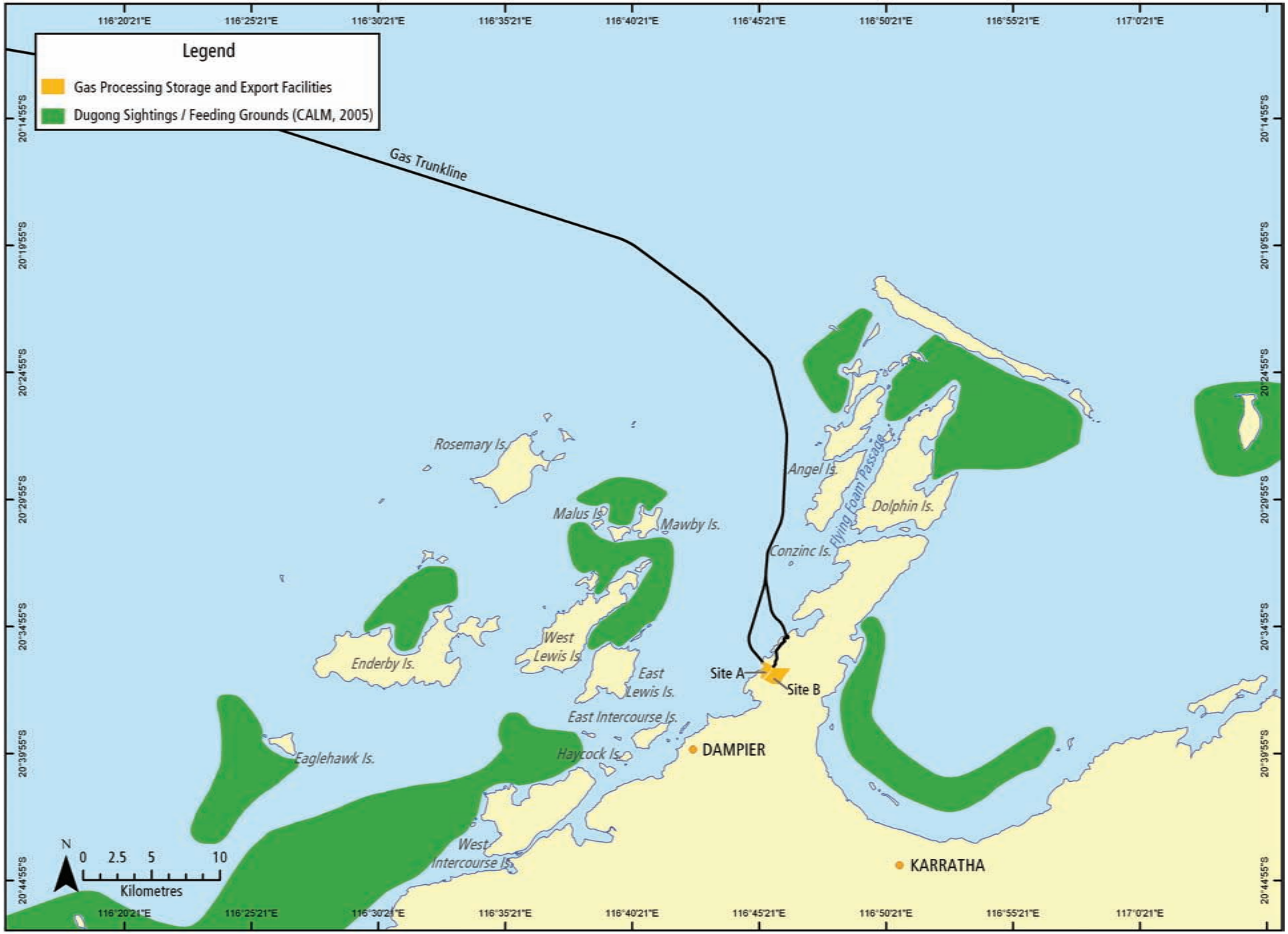


Figure 6-17 Humpback Whale Migration

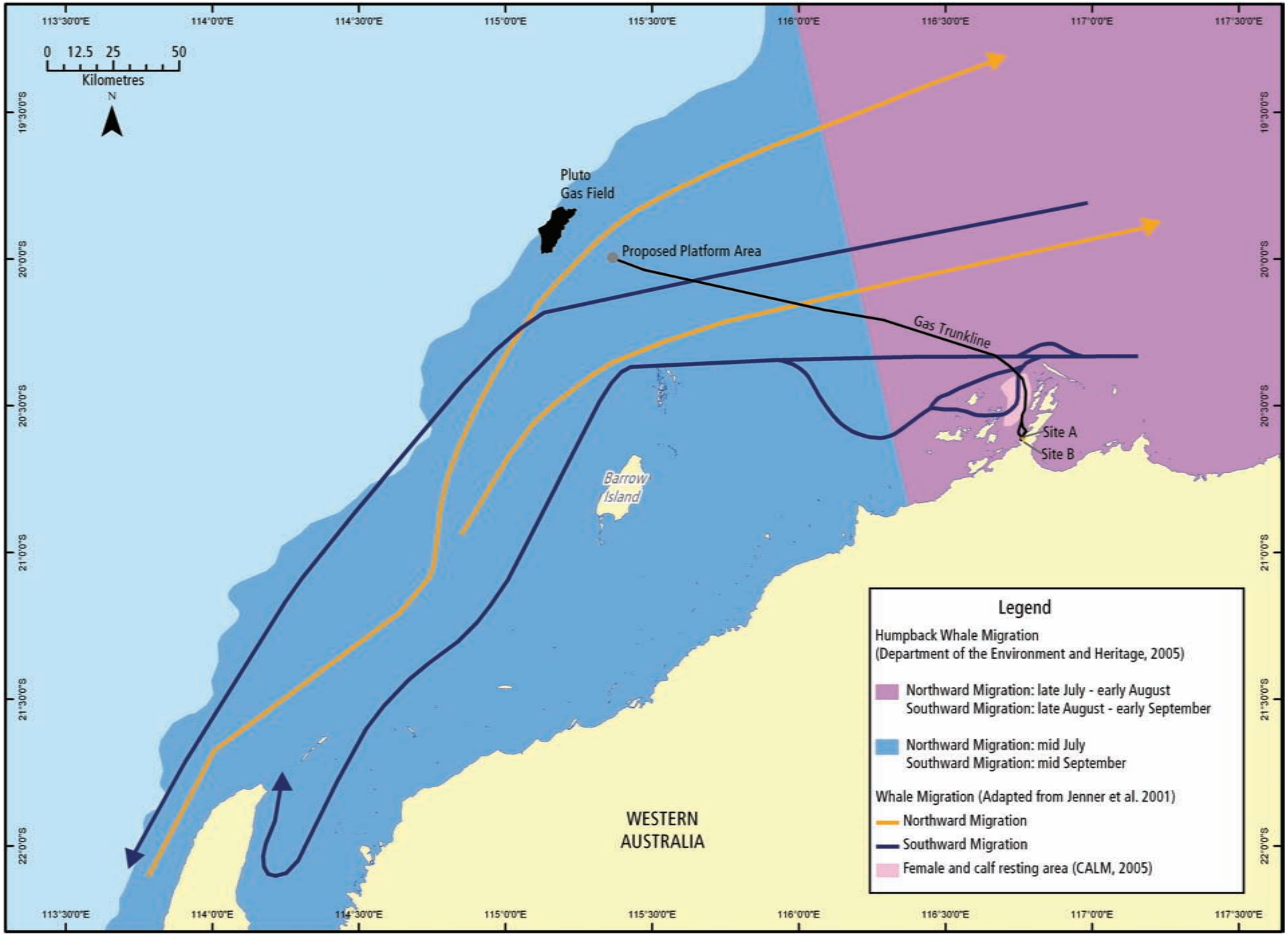


Table 6-4 Dolphin and Whale Species Recorded from the Pilbara Coastal Region

Common Name	Scientific Name	Distribution	Notes
Dolphins			
Bottlenose dolphin	*Tursiops truncatus*	Worldwide Temperate and tropical waters, in coastal, estuarine and oceanic habitats. Recorded throughout Australia, occasionally recorded in sub-Antarctic waters. Common in WA.	Inshore forms feed on fish and invertebrates from the littoral and sub-littoral zones. The offshore form commonly feeds on mesopelagic fish and oceanic squids.
Common dolphin	*Delphinus delphis*	Widely distributed in warm temperate and tropical waters of the Atlantic, Pacific, and probably Indian oceans. Recorded in all Australian states and the NT.	The common dolphin is an opportunistic feeder whose diet includes schooling fish (for example, sardines) and cephlapods.
Indo-Pacific humpback dolphin	*Sousa chinensis*	Discontinuously distributed in tropical and subtropical coastal waters of the western Pacific. Recorded from the north-western coast of WA from North West Cape to as far south as Shark Bay; and the coast of eastern Australia from Cairns in Qld to Wollongong in NSW.	Coastal species that occurs in waters less then 20 m deep, and is often associated with estuarine systems, sheltered bays, mangrove areas and seagrass meadows. This species has a varied diet including fish, some cephalopods and crustaceans.
Orca (killer whale)	*Orcinus orca*	Worldwide distribution throughout all oceans and contiguous seas from equatorial to polar regions. Recorded in all states but the NT. Often seen along continental slope and Shelf. Regularly seen near seal colonies.	Top-level carnivore. Specific diet of Australian killer whale not known but there are reports of attacking 'dolphins', young humpbacks, blue whales, sperm whales, dugongs and sea-lions.
Risso's dolphin	*Grampus griseus*	Widely distributed species, inhabiting deep oceanic and continental slope waters 400–1000 m deep from the tropics through the temperate regions in both hemispheres.	Recorded in all states but the NT. Feeds in pelagic waters primarily on squid, some octopus and possibly fish.
Spinner dolphin	*Stenella longirostris*	All tropical and subtropical waters around the world from 30–40°N and 20–30°S. In Australia, recorded from WA (furthest south record Bunbury), NT, Qld and NSW. Not known to be migratory.	It is possible that the southern distribution of the spinner dolphin in WA is related to warm waters of the Leeuwin Current. Spinner dolphins are believed to feed on reef and benthic organisms, mesopelagic fish and squid.
Striped dolphin	*Stenella coeruleoalba*	World-wide distribution in tropical and temperate waters. The southern limit of its range is Buenos Aires in Argentina, Cape Province, WA, New Zealand, and Peru. Recorded from WA (south to Augusta), Qld and NSW.	Generally inhabit deep waters and areas along the edge of the continental shelf. Pelagic, travel in large groups of several hundreds and even thousands of individuals. Small prey (<300 mm length), including mesopelagic fish, shrimp and squid.
Irrawaddy dolphin	*Orcaella brevirostris*	Irrawaddy dolphins are found in the Indo-Pacific, from north-eastern Australia in the south, north to the Philippines, and west to north-eastern India. In Australia they are reported in the NT, and in Queensland, north of Gladstone. Also in WA north of and including Broome; however, recent anecdotal evidence suggests they may be found as far south as Carnarvon.	Usually in groups of <6, occasionally in groups of up to 15. Feeds on teleosts, cephalopods and crustaceans.

Common Name	Scientific Name	Distribution	Notes
Whales			
Beaked Whale	Blainville's Beaked Whale (*Mesoplodon densirostris*)	Blainville's beaked whale prefers tropical and warm temperate waters around the world including waters off western and eastern Australian coasts.	Blainville's Beaked Whale diet is little known, appears to consist of mid- and deep-water squid and fish.
	Cuvier's Beaked Whale (*Ziphius cavirostris*)	Cuvier's Beaked Whale has been recorded by strandings in all Australian states and Northern Territory, mostly from January to July, suggesting some seasonality of occurrence.	Cuvier's Beaked Whales feed mostly on squid and fish. Known to strand quite frequently.
Blue whale	*Balaenoptera musculus* Two subspecies: Southern hemisphere *Balaenoptera musculus intermedia* Pygmy blue whale *Balaenoptera musculus brevicauda*	Oceanic, worldwide, but not limited to deeper waters. Extensive migrations between warm water (low latitude) breeding and cold water (high latitude) feeding grounds; in southern hemisphere, between latitudes approx 20°S and 60–70°S. Pygmy blue subspecies occurs only in southern hemisphere, particularly in Indian Ocean, and migrates less far south. In Australia, blue whales are found in the waters off Australia's Antarctic Territory, and along the southern parts of the Australian coast from WA to southern Qld. The majority of the most northerly sightings are likely to be pygmy blue whales. Significant aggregations in WA recorded at Geographe Bay and in the Perth Canyon off Rottnest Island. The pygmy blue whale has been sighted within a few miles of the Dampier Archipelago.	Blue whales, probably mostly pygmy blues, feed mainly on the neritic krill *Nyctiphanes australis* off western Victoria and south-east South Australia. Feeds in areas of upwellings along the continental shelf. Canyon systems in Pluto gas field may provide suitable habitat for pygmy blue whales (C Jenner [Managing Director, Centre for Whale Research] 2005 pers comm.17 November).
Bryde's whale	*Balaenoptera edeni*	Restricted to tropical and temperate waters, both inshore and offshore, from the equator to ca 40°S. Recorded in all Australian states except the NT. Sightings in WA include the Abrolhos Islands and inshore waters north of Shark Bay.	Due to similarities in appearances, it is difficult to distinguish Bryde's whales from sei whales, therefore records are somewhat unreliable. Inshore forms feed very largely on shoaling fish e.g. anchovies, offshore forms on euphausiids.
False killer whale	*Pseudorca crassidens*	Found world-wide in tropical and temperate waters. It ranges north to Scotland, southern Japan, Hawaii and Canade, and south to Argentina, Africa, Australia, New Zealand and Chile. Widely recorded by strandings and some sightings in waters of all Australian states.	Generally found off the continental slope and only approaches the coast where the continental shelf is narrow. It feeds on cephalopods and large pelagic fish such as cod (*Gadus* spp.), mahi mahi (*Coryphaena*), yellowtail tuna (*Pseudosciena*) and salmon (*Onchorhynchus*).
Humpback whale	*Megaptera novaeangliae*	Migratory, worldwide distribution. Antarctic pelagic, in summer; temperate–subtropical/tropical coastal in winter. In Australia, humpback whales are distributed in waters of all Australian states and the Antarctic. Key localities in WA include Cape Naturaliste/ Geographe Bay, north of Rottnest Island, Shark Bay, North West Cape, off Dampier Archipelago, coastal islands off Kimberley.	Migrate from Southern Ocean summer feeding grounds to sub-tropical winter calving grounds. Australia has two migratory populations of humpback whales, a west coast and an east coast population. Feed mainly in Antarctic waters, that is south of 55°S. In southern hemisphere feed almost exclusively on *Euphausia superba* (krill).

Common Name	Scientific Name	Distribution	Notes
Minke whale	*Balaenoptera acutorostrata*	Migratory, worldwide. Generally oceanic, although it has been sighted in coastal waters. Recorded in all Australian states except the Northern Territory.	Travel between warm water breeding grounds and cold water feeding grounds. Southern hemisphere animals (dark-shoulder form) feed predominantly on *Euphausia superba* and some smaller euphausiid species.
Pilot whale	*Globicephala macrorynchus*	Tropical to temperate oceanic waters. Circumglobal distribution, equatorial to c. 41°S and c. 45°N. Evidence of genetically distinct populations in northern and eastern Pacific Ocean. Distribution in Australia includes oceanic waters and continental seas. Strandings in all states except Victoria.	Socially cohesive, in small groups of 10 to 30, but commonly in herds of several hundred; often accompanied by dolphins. Feeds mainly on squid, cuttlefish and octopus and some fish.
Sei whale	*Balaenoptera borealis*	Worldwide, oceanic. Migrate between warm water breeding grounds and colder water feeding grounds, but in southern hemisphere do not migrate as far south as other baleen whales. More deep-water than close relative Bryde's whale, not often found near coasts. In frequently recorded in Qld, WA, the Great Australian Bight and Tasmania.	Due to similarities in appearances, it is difficult to distinguish sei whales from Bryde's whales, therefore records are somewhat unreliable. Feed mainly on pelagic copepods (*Calanus* spp.), also occasionally euphausiids, amphipods.
Sperm whale	*Physeter macrocephalus*	Worldwide distribution. Occurs in deep water, off continental shelf, i.e. beyond 200 m depth. Recorded from all Australian states. In some areas of WA, where the slope of the continental shelf is less steep, sperm whales are more widely dispersed offshore, while in areas such as the continental shelf edge near Albany, concentrations of sperm whales in a narrow area can be found.	Females and young males tend to stay in warm northern waters, while solitary mature males travel to and from cold southern waters. Feed in areas of upwellings, mainly on deep sea cephalopods.

Source: Compiled from Bannister et al. 1996; CALM 2005; DEH 2005b and, 2005c; C Jenner [Managing Director, Centre for Whale Research] pers comm.17 November 2005

6.3.7 Birds

The Burrup Peninsula and Dampier Archipelago contain a range of habitats that are productive feeding grounds for a variety of endemic and migratory marine birds. Seabirds and shorebirds in the area also utilise the many islands of the Archipelago and the beaches of the Burrup Peninsula as nesting and roosting sites. Various species of seabirds and shorebirds nest on the islands of the Dampier Archipelago throughout the year, but mostly in winter (CALM 1990). While many marine birds are resident in the area throughout the year, the area also provides habitat for a variety of migratory shorebird species that journey from Asia and the Arctic Circle to feed on the worms, bivalves and other invertebrates in the area's intertidal sand and mud flat and mangrove communities (CALM 2005).

Shorebirds

Shorebirds and wading birds inhabit mangroves, mudflats, sandy intertidal flats and adjacent areas in the Burrup Peninsula and Dampier Archipelago, and include the mangrove kingfisher (*Halcyon senegaloides*), the sacred kingfisher (*Todiramphus sanctus*), the striated or mangrove heron (*Butorides striatus*), the great egret (*Adrea alba*) and the white-breasted whistler (*Pachycephala lanioides*) (CALM 1990). The productive feeding grounds in the area represent an essential part of a relatively large home range for migratory birds that rely upon feeding grounds to supply sufficient energy for migration and breeding (CALM 1990; Worley Astron 2005). Shorebirds which breed locally may have a much smaller home range and often rely upon access to these local resources to support all parts of their life cycle.

Numerous shorebirds inhabit sandy beaches, rocky beaches, sand and mud flats and shallow rock platforms in the Dampier Archipelago including the curlew sandpiper (*Calidris ferruginea*), black-tailed godwit (*Limosa limosa*), the red-capped plover (*Charadrius ruficapillus*), sooty oystercatcher (*Haematopus fuliginosus*), pied oystercatcher (*Haematopus longirostris*) and beach stone curlew (*Esacus neglectus*) (Schodde and Tidemann 1990; Simpson and Day 2004). These birds utilise a wide range of habitats and have a variety of diets, for example, the pied oystercatcher (*Haematopus longirostris*) feeds on bivalve and cone molluscs found on wet sandy flats and bars while the beach stone curlew (*Esacus neglectus*) searches for crustaceans and hard shelled marine invertebrates on wet sand, shallow reef and rocky shores (Schodde and Tidemann 1990).

Coastal raptor species found in the Dampier Archipelago that mainly feed on fish include the white-bellied sea-eagle (*Haliaeetus leucogaster*), osprey (*Pandion haliaetus*) and brahminy kite (*Haliastur indus*) (CALM 1990). The white bellied sea-eagle (*Haliaeetus leucogaster*) has a wide distribution along coastlines, large lowland rivers and lakes, whilst the osprey (*Pandion haliaetus)* tends to be found along coastlines and some inlets. Brahminy kites (*Haliastur indus*) inhabit mangrove-lined coastal inlets and bays, as well as mud flats, rocky shores and beaches (Schodde and Tidemann 1990).

Islands and islets within the Archipelago including Goodwyn Island, Keast Island and Nelson Rocks, provide important undisturbed nesting and refuge sites for many shorebirds. Keast Island provides one of the few nesting sites for the Australian Pelican (*Pelecanus conspicillatus*) in Western Australia (CALM 2005).

Seabirds

Seabirds generally use the marine environment for food, returning to land to roost or breed. Groups of sooty terns (*Sterna fuscata*), wedge-tailed shearwaters (*Puffinus pacificus*) and the occasional frigatebird (*Fregata* spp.) have been sighted foraging throughout the North West Shelf area, though most sightings of seabirds in the north-east Indian Ocean are typically clumped in areas adjacent to islands (Woodside 2002). Masked boobies (*Sula dactylatra*) and species of storm petrel have been observed within Mermaid Sound (Astron 2002).

Many of the islands and rocks in the area are known breeding grounds for a variety of seabirds. The nearby Conzinc Island provides breeding habitat for the wedge-tailed shearwater (*Puffinus pacificus*), Caspian tern (*Sterna caspia*) and fairy tern (*Sterna neireis*), while the following species were observed to roost on the Island: silver gulls (*Larus novaehollandiae*), crested terns (*Sterna cristata*), roseate terns (*Sterna dougalli*), bridled terns (*Sterna anaethetus*) (CALM 1999) and lesser crested terns (*Sterna bengalensis*) (Worley Astron 2005). Seabirds may also use the beach and coastal rocks on the west side of the Burrup Peninsula for roosting and feeding. Pelagic seabirds such as the wedge-tailed shearwaters, generally do not visit land other than their breeding colony.

6.3.8 Marine Fauna of Conservation Significance

Commonwealth Protected Fauna

A search of the DEH protected matters search tool (DEH 2005a) indicated that 35 fish species, 22 marine reptile species, 27 marine mammal species and 19 sea and shorebird species listed under the EPBC Act may occur within or migrate through the Development area. Full lists of species protected under this Act that could occur in the area, including those listed as migratory, cetaceans and marine species are presented in **Appendices B–E**. Marine species listed as threatened under the EPBC Act, which may occur within or migrate through the Development area, are presented in **Table 6-5**.

Table 6-5 Threatened Marine Fauna Protected under the EPBC Act

Scientific Name	Common Name	Status	Type of Presence
Fish Species			
Rhincodon typus	Whale shark	Vulnerable, migratory	Species or species habitat may occur within area
Marine Reptile Species			
Chelonia mydas	Green turtle	Vulnerable, migratory	Species or species habitat may occur within area
Caretta caretta	Loggerhead turtle	Endangered, migratory	Species or species habitat may occur within area
Dermochelys coriaceaa	Leathery turtle, leatherback turtle	Vulnerable, migratory	Species or species habitat may occur within area
Eretmochelys imbricata	Hawksbill turtle	Vulnerable, migratory	Species or species habitat may occur within area
Natator depressus	Flatback turtle	Vulnerable, migratory,	Species or species habitat may occur within area
Marine Mammal Species			
Balaenoptera musculus	Blue whale	Endangered, migratory, cetacean	Species or species habitat may occur within area
Megaptera novaeangliae	Humpback whale	Vulnerable, migratory, cetacean	Species or species habitat may occur within area
Bird Species			
Macronectes giganteus	Southern giant petrel	Endangered, migratory	Species or species habitat may occur within area

Source: DEH 2006

Fish

Whale sharks (*Rhincodon typus*) are listed as vulnerable under the EPBC Act. They aggregate annually around Ningaloo Reef, over 100 km south-west of the Development area, with the main aggregation period being late March to July, probably in response to local food availability (DEH 2006). Whale sharks may traverse areas of the Pluto LNG Development at this time.

Pipefish, pipehorses and sea horses (of the family Sygnathidae) are widely distributed in Western Australian waters and many have been recorded throughout the Dampier Archipelago by Hutchins (2003) in a variety of habitats. These fish are listed as marine species under the EPBC Act and are therefore protected. The DEH database indicates that 34 species of listed pipefish and seahorses may occur within the area of the Pluto LNG Development (**Appendix B**). Listed species recorded by Hutchins (2003) for the Dampier Archipelago are also shown in **Appendix B**. It is assumed that other listed species may be present in the Dampier Archipelago with the exception of *Hippocampus kuda*, which is listed by the EPBC Act but is not known from Australian waters.

Marine Reptiles

Green, flatback, leatherback and hawksbill turtles are listed as vulnerable under the EPBC Act. Loggerhead turtles are listed as endangered under the EPBC Act. Turtles are discussed in detail in **Section 6.3.5**.

The DEH database identifies a total of 17 seasnakes as potentially being present within the project area (**Appendix C**). These species are included under the EPBC Act as listed marine species. It is recognised that whilst these species usually occur in marine habitats, there is the possibility they may be found in intertidal zones near Site A. Seasnakes are discussed in detail in **Section 6.3.5**.

Marine Mammals

A total of 27 species of whale and dolphin could potentially be present within the Development area (**Appendix D**). The blue whale *Balaenoptera musculus* is listed under the EPBC Act as endangered. Humpback whales, which are known to migrate through the Development area, are listed under the EPBC Act as vulnerable. The other whale and dolphin species found within the Development area are listed as migratory and/or marine species and are hence protected under the EPBC Act.

The dugong, which is likely to occur within the Development area, is listed as migratory and as a marine species under the EPBC Act.

Birds

The southern giant petrel (*Macronectus giganteus*), although listed by the EPBC protected matters search tool as potentially occurring on the Burrup Peninsula, is unlikely to occur at such low latitudes and is highly unlikely to be present with the Pluto LNG Development, in its healthy state, away from its usual habitat.

A total of 11 species, listed as migratory and marine species, have been identified as potentially occurring within the Development area by the protected matters search tool, including the wedge-tailed shearwater, bridled tern and Caspian tern (**Appendix E**). A further seven species, listed as marine species, have been identified as potentially occurring within the Development area, including the crested tern, roseate tern and the fork-tailed swift.

State Protected Fauna

The *Wildlife Conservation Act 1950* (WA) provides for the protection of native fauna, with species considered as needing special protection listed under one of four categories in the Wildlife Conservation (Specially Protected Fauna) Notice, these being:

- Schedule 1 – fauna that are rare or likely to become extinct
- Schedule 2 – fauna presumed to be extinct
- Schedule 3 – birds that are subject to the Japan Australia Migratory Bird Agreement (JAMBA), which relates to the protection of migratory birds and birds in danger of extinction
- Schedule 4 – other specially protected fauna.

The following marine species which have been recorded from the Pilbara region, are specifically protected under the *Wildlife Conservation Act 1950* (WA):

- southern giant petrel (*Macronectus giganteus*) – Schedule 1
- loggerhead turtle (*Caretta caretta*) – Schedule 1
- green turtle (*Chelonia mydas*) – Schedule 1
- leathery turtle, leatherback turtle (*Dermochelys coriaceaa*) – Schedule 1
- hawksbill turtle (*Eretmochelys imbricata*) – Schedule 1
- flatback turtle (*Natator depressus*) – Schedule 1
- dugong (*Dugong dugon*) – Schedule 4
- blue whale (*Balaenoptera musculus*) – Schedule 1
- humpback whale (*Megaptera novaeangliae*) – Schedule 1
- Indian yellow-nosed albatross (*Thalassarche carteri*) – Schedule 1
- Atlantic yellow-nosed albatross (*Thalassarche chlororhynchos*) – Schedule 1
- masked booby (eastern Indian Ocean) (*Sula dactylatra bedouti*) – Schedule 1
- Australian painted snipe (*Rostratula benghalensis australis*) – Schedule 1
- Barrow Island black-and-white fairy-wren (*Malurus leucopterus edouardi*) – Schedule 1
- grey nurse shark (*Carcharias taurus*) – Schedule 1
- saltwater crocodile (*Crocodylus porosus*) – Schedule 4.

In addition to those species protected under the *Wildlife Conservation Act 1950* (WA), a number of species are listed as Priority species by the DEC. Although not conferred legal protection, these species have been identified as being significant. The following marine species which have been recorded from the Pilbara region have been listed as Priority fauna:

- sperm whale (*Physeter macrocephalus*) – Priority 4
- Indo-Pacific humpback dolphin (*Sousa chinensis*) – Priority 4
- spinner dolphin (*Stenella longirostris*) – Priority 4.

International Agreements

Migratory bird species including waders, which commute between Australia and Northern Asia, may pass through or near the offshore areas of the Pluto LNG Development on their way to islands and the Pilbara coastal habitats. An international agreement between the Government of Australia and the Government of Japan, JAMBA, protecting many of these birds, was ratified in 1981 under the *National Parks and Wildlife Conservation Act 1975* (Cwth) (since replaced by the EPBC Act). There is a similar agreement with China, known as CAMBA.

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. The provisions of this convention have been incorporated into the EPBC Act.

Marine Impacts and Management 7

7.1 Introduction

This section of the Draft PER identifies the potential marine impacts from the proposed Pluto LNG Development and associated preventative and management strategies that will be implemented to reduce impacts to an acceptable level.

The impact assessment covers the marine construction, operational and decommissioning activities described in **Section 4**, broadly comprising:

- subsea wells tied back to a riser platform
- a gas trunkline to a landfall on the Burrup Peninsula
- navigation channel, turning basin and berth pocket
- an off-loading platform and berth
- disposal of treated waste water to Mermaid Sound
- disposal of dredge spoil at spoil disposal grounds.

Activities associated with the Development have been assessed through a comprehensive impact assessment process which has been verified using the Woodside corporate risk assessment tool described in **Section 7.2**. This process allows potential environmental impacts to be systematically identified and considered on the basis of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk to the environment.

It should be recognised that a formal risk assessment of environmental issues is only one of the tools employed to identify and rank the key environmental impacts of the Pluto LNG Development. The value of the risk assessment is as a high-level screening tool, to identify the impacts that require detailed assessment. The results of the risk assessment should not be interpreted in isolation from the broader assessment process described within this Draft PER.

7.2 Risk Assessment Methodology

7.2.1 Overview

Risk can be defined as the product of the potential consequence of an event and the likelihood (or probability) of that consequence occurring.

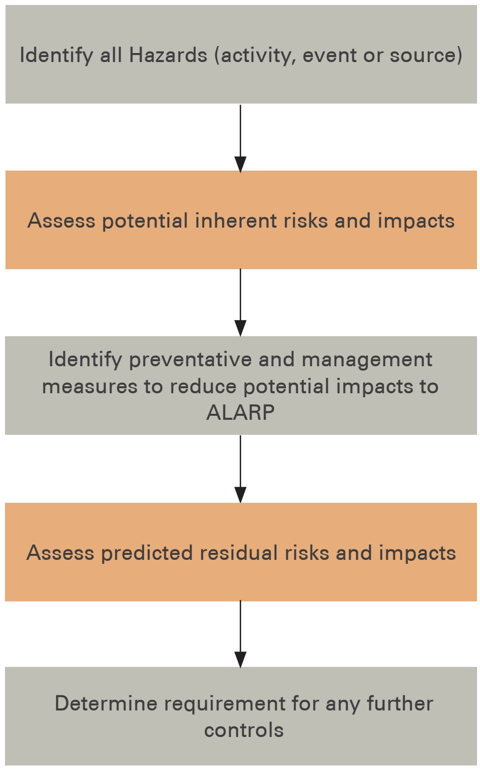
The risk assessment methodology used in this Draft PER is consistent with the methods applied by Woodside in managing risks associated with all of its development opportunities and projects and also with standard risk management process and practice as outlined in the Australian risk management standard (AS/NZS 4360).

The key steps are outlined below and illustrated in **Figure 7-1**. They include the following:

- setting the environmental risk context, including objectives, proposed activities and location
- identifying the environmental hazards
- identifying the potential environmental effects resulting from release of those hazards
- analysing risk using qualitative and quantitative information on potential likelihood and consequences associated with release of hazards
- identifying appropriate safeguards and management control measures (including prevention and mitigation barriers)
- analysing the predicted residual risks for defined aspects and hazards with consideration of the proposed safeguards and controls to be in place.

The key elements of the risk methodology are discussed further in the following sections.

Figure 7-1 Risk Assessment Process



7.2.2 Hazard Identification

A hazard may be defined as a substance, or situation, that is a source of potential harm. For the harm to be realised it is necessary for there to be an event that results in the release of the hazard.

The hazard identification process has been conducted to firstly identify all those substances or situations that represent a hazard and secondly to identify the events that may lead to these hazards being realised. An additional stage in this process is the identification of protection measures or procedures to mitigate these events and hazards.

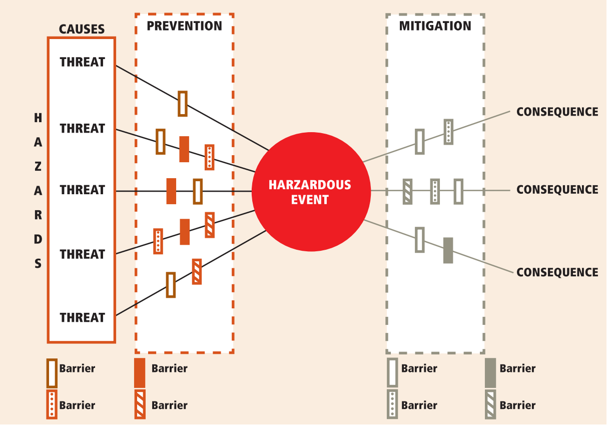
The main sources of input to the hazard identification process included:

- issues raised during public consultation (**Section 2**)
- knowledge developed by Woodside from the company's extensive prior experience in assessing and operating offshore oil and gas facilities
- formal hazard identification studies conducted by Woodside, which included:
  - a review of development design
  - workshops with key personnel
  - the use of detailed checklists to prompt for possible hazards, pathways and impacts.

In identifying hazards, consideration has been given to exposure to normal as well as extreme conditions (for example, cyclones, tsunamis).

Hazard management requires consideration of both the prevention and the management measures that may be proposed or developed to control and minimise undesirable consequences should a hazard be released. The relationship between the threat of an undesirable event happening and the likely consequence of that event is illustrated by the bow tie diagram shown in **Figure 7-2**.

Figure 7-2 'Bow Tie' Diagram of Hazards and Barriers



The left-hand side of the bow tie indicates the hazard, which may be associated with a number of identifiable threats. A number of barriers to these threats may be in place that will reduce the primary risk of the event occurring (threat barriers). The right hand side of the bow tie shows the potential consequences. A number of barriers may be put in place to avoid or minimise escalation of the event into a larger consequence or transference of the hazard to other areas (escalation barriers). Threat barriers and escalation barriers may take several forms and are the measures underpinning effective risk management.

7.2.3 Characterising Environmental Risk

Environmental risk assessment is a process that evaluates the likelihood and consequences of adverse environmental effects that may occur as a result of exposure to one or more hazards. The process of environmental risk assessment applied in this Draft PER has been structured to systematically evaluate and organise data, information, assumptions and uncertainties in order to help understand and predict the relationships between hazards and environmental effects in a way that is useful for environmental decision-making. The assessment has included consideration of chemical, physical, or biological stressors on biota and ecological processes combined with regulatory guidelines, standards and ecological values.

Knowledge of the likelihood of an environmental hazard being released as an event, and the assessment of the environmental consequences from that event, are used to characterise the level of environmental risk associated with particular hazards. The environmental consequence categories are defined by a set of qualitative category descriptions shown in **Figure 7-3**.

Appropriate levels of risk are assigned to particular hazards using a risk matrix that comprises the defined categories of likelihood, or probability, of the event happening and the defined categories of environmental consequence from that event (**Figure 7-3**). In assessing appropriate risk levels, consideration is given to the safeguards, controls and management measures that are proposed or in place that reduce the inherent risk. The risk matrix is used to assign a level of assessed residual environmental risk to particular aspects and hazards.

The characterisation of environmental risks for particular aspects and hazards identified for the proposed Pluto LNG Development allows Woodside to implement appropriate environmental management measures, which are described further in **Section 13**.

The characterisation of environmental risk into these various levels also enables Woodside to implement additional environmental management controls, especially for severe and high risks, to reduce the residual risk level and/or ensure that the risk is ALARP.

This section identifies the potential environmental impacts and defines preventative and management strategies for the environmental factors associated with the proposed Pluto LNG Development.

7.3 Summary of Relevant Impacts and Risks

The impact assessment concluded that the vast majority of marine impacts can be categorised as having short-term consequences on the environment and will be managed through the implementation of routine mitigation and management measures. Priority has been given to development of management measures to address the following potential impacts:

- Seabed disturbance during construction activities (**Section 7.5**).
- Physical presence of vessels within Dampier Archipelago and the wider development area (**Section 7.4**).
- Dredging and spoil disposal (**Section 7.9**).
- Potential introduction of marine pest species into nearshore waters (Dampier Archipelago) (**Section 7.7**).
- Introduction of residual chemicals into offshore waters from discharge of hydrotest water (**Section 7.8.6**).
- Discharge of treated waste water in nearshore waters during operations (**Section 7.8.13**).
- Accidental hydrocarbon spills within the Dampier Archipelago (**Section 7.10**).
- Marine blasting during construction (**Section 7.12**).

To address higher priority impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to acceptable levels. Key mitigation and management measures include:

- Preventing dredging operations during coral mass spawning events in areas where activities may adversely affect corals or coral larvae settlement.
- Reducing impacts associated with propeller wash, as far as reasonably practicable by targeting dredging of shallow areas to times when the dredge vessel is empty and/or coincide with high tide.
- Limiting anchor and anchor chain interference with coral communities and sponge community assemblages by anchoring outside these areas.
- The final gas trunkline option will be routed to minimise seabed disturbance to sensitive areas where practicable.
- Movement of vessels other than vessels with limited manoeuvrability (for example, tankers) will be conducted in accordance with the requirements of the EPBC Act and Regulations regarding maintenance and avoidance of marine mammals.
- A Dredging and Spoil Disposal Management Plan (DSDMP) will be supported by a suite of monitoring programmes including a baseline pre-dredge study on sedimentation and coral health, predictive forecast modelling, monitoring of physical and biological indicators and a post-dredge baseline study of coral health to determine delayed effects.
- Where the potential risk is considered to be high, one or more options for management of ballast water will be implemented, such as no discharge of 'high risk' ballast tanks in Australian waters or tank-to-tank transfers.
- An environmental plan covering flooding, hydrotesting and pre-commissioning activities will be submitted to the regulatory authority for review and approval.
- The residual total hydrocarbon in water concentration of treated waste water discharged will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound.
- A number of engineering measures will be implemented to prevent hydrocarbon spills from occurring during operations.
- Procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence.

Figure 7-3 Risk Matrix

	Biodiversity and Ecological Processes			Environmental Quality			
	Protected Species	**Marine Primary * Producers**	**Ecological Diversity**	**Water Quality ****	**Marine Sediment Quality****	**Air Quality**	**Soil and Ground Water Contamination**
CONSEQUENCE	Eradication of local population Loss of critical habitats or activities Eradication of local population/s Mass mortality of fauna and flora. Loss of critical habitats.	Permanent eradication of primary producers on a regional scale	Permanent effects on ecosystem diversity on a regional scale	Continuous or regular contamination to water quality above national/ international standards &/or known biological effect concentrations on a regional scale (> 100 Km^2)	Permanent contamination above background &/or national / international quality standards &/or known biological effect concentrations on large -regional scale	Continuous exceedances over national / international air quality standards Damage to the environment or human health	Permanent off site contamination of ground water &/or soil. Cost effective treatment not possible Damage to the environment or human health
	Extensive impact on population (s) Significant impact on critical habitats or activities Significant mortality of fauna and flora. Significant impact on critical habitats.	Large scale and long term effects Recovery > 10 years or permanent	Large scale long term effects on ecosystem diversity Recovery > 10 years or permanent	Continuous or regular discharge with contamination above background &/or national / international quality standards &/or known biological effect concentrations on large scale (10 -100 Km^2)	Long term contamination above background &/or national / international quality standards &/or known biological effect concentrations on large scale	Sustained, exceedance over national / international air quality standards Potential harm to the environment or human health	Extensive off site contamination of ground water &/or soil. Treatment difficult / expensive Potential threat to the environment or human health
	Minor disruption to a significant portion of the population Minor impacts on critical habitats or activities No threat to overall population viability. Disruption to a significant portion of the population Major mortality of fauna and flora. Major impacts on critical habitats.	Moderate or large scale effect recovery within 10 years	Localised but long term effect on ecosystem diversity. Community/habitat maintains ecological integrity though an unacceptable change in species composition may occur Localised long term or widespread medium term effect on ecosystem diversity. Regional ecological diversity maintained though an unacceptable change in species composition may occur	Continuous or regular discharge with contamination above background &/or national / international quality standards &/or known biological effect concentrations on medium scale (1-10 Km^2)	Short to medium term contamination above background &/or national / international quality standards &/or known biological effect concentrations on large scale	Temporary exceedance over national / international air quality standards Potential harm to the environment or human health	Extensive contamination of ground water &/or soil, offsite contamination probable, treatment difficult / expensive Limited threat to the environment or human health
	Minor disruption or impact on a small portion of the population. Minor and temporary impact on critical habitat or activity No threat to overall population viability. Moderate disruption or impact on a small portion of the population. Moderate mortality of fauna and flora. Minor and temporary impact on critical habitat	Localised effect recovery in either medium or long term	Localised medium term effect on ecological diversity. Community/habitat maintains ecological integrity though an acceptable change in species composition may occur Regional ecological diversity maintained though a tolerable change in species composition may occur	Continuous or regular discharge with contamination above background &/ or national/international quality standards &/ or known biological effect concentrations on local scale (< 1 Km^2)	Short-medium term contamination above background &/or national / international quality standards &/or known biological effect concentrations on medium scale	Temporary exceedance over national / international air quality standards No harm to the environment or human health expected	Moderate contamination of ground water or soil, contained within site boundary, treatment difficult / expensive. No threat to the environment or human health
	Minor and Temporary disruption to small portion of the population. No impact on critical habitat or activity. Minor mortality of fauna and flora. Limited permanent loss of habitat. No impact on critical habitat	Localised and short term effect on key primary producers Recovery < 5 years	Localised and short - medium term effect on ecological diversity Full recovery expected Localised short to medium term or limited permanent effects on ecological diversity. Limited impacts or full recovery expected	Temporary discharge with contamination above background levels & or national/international quality standards &/ or known biological effect concentrations on local-medium scale (< 10 Km^2)	Temporary contamination above background &/or national / international quality standards &/or known biological effect concentrations on local-medium scale	Minor and temporary exceedance over national / international air quality standards No harm to the environment or human health expected	Minor contamination of ground water or soil, contained within site boundary, readily treated. No threat to the environment or human health
	Negligible Effect	Negligible Effect	Negligible Effect	Negligible Effect	Negligible Effect	Negligible Effect	Negligible Effect

* Assessment must consider cummulative impacts within a defined management area / unit when assessing significance. As a rule cummulative recoverable loss of habitat and marine primary producers within a defined managemenet area/unit should not exceed 10%

Societal					LIKELIHOOD					
					0	1	2	3	4	5
Protected Areas	Cultural	Compliance			Remote	Highly Unlikely	Unlikely	Possible	Quite Likely	Likely
Significant permanent effect on one or more of protected areas values	Significant permanent impact on aesthetic, economic or recreational values Overall societal benefits do not outweigh impacts	Continuos licence / regulatory exceedances Fines or prosecutions incurred / expected	A+	Catastrophic					SEVERE	
Significant long term effect on one or more of protected areas values	Significant long term impact on aesthetic, economic or recreational values Overall societal benefits do not outweigh impacts	Regular or ongoing licence / regulatory exceedances Fines or prosecutions likely	A	Massive						
Minor but long term or permanent effect on one or more of protected areas values	Moderate impact on aesthetic, economic or recreational values. Overall societal benefits do not outweigh impacts	Repeated licence / regulatory / target / exceedance No fines or prosecutions	B	Major			HIGH			
Minor and medium term effect on one or more of protected areas values Full recovery expected	Moderate impact on aesthetic, economic or recreational values but overall societal benefits outweigh impacts	Frequent licence / regulatory / target / exceedence No fines or prosecutions	C	Moderate		MEDIUM				
Minor and short term effect on one or more of protected areas values Full recovery expected	Minor and temporary impact on aesthetic, economic or recreational values	Occasional licence / regulatory / target exceedance No fines or prosecutions	D	Minor		LOW				
Negligible Effect	Negligible Effect	Negligible Effect	E	Slight						

7.4 Physical Presence

Potential Impacts

This section identifies the potential environmental impacts associated with the presence of Development-related infrastructure within nearshore and offshore waters. Potential impacts are discussed in relation to:

- infrastructure present for the life of the Pluto LNG Development (including subsea manifolds, flowlines, offshore platform, gas trunkline, jetty and causeway)
- vessels in the Dampier Archipelago and on the North West Shelf.

Infrastructure: The presence of offshore facilities has the potential to act as artificial habitat. The platform legs, flowlines and manifolds represent hard substrate, providing a foundation for the colonisation of encrusting organisms. Planktonic organisms attach to structures and remain attached in adulthood, leading to the development of an often diverse, fouling community that is likely to include filter-feeding organisms such as sponges, ascidians, soft corals and barnacles as well as a variety of mobile invertebrates.

Structures proposed for the Pluto LNG Development that may provide an artificial habitat for colonisation by marine organisms include:

- offshore platform including legs/moorings
- manifolds and flowlines
- gas trunkline and associated rock dump
- glycol supply line
- jetty and causeway.

Once established, the structures and their associated colonies will attract a variety of fish and other organisms that may utilise the newly formed habitat for aggregation, food and/or refuge. The colonisation of new habitat generally stabilises over time and any ecological effects are localised. In offshore areas where the wellhead flowlines and platforms are likely to be located, existing ecological macrobiotic communities are primarily either pelagic or associated with soft sediments. The types of fouling organisms expected to occur on hard structures associated with the Pluto LNG Development are likely to be the same as those observed at the North Rankin A and Wanea-Cossack facilities located on the North West Shelf as well as on other structures in the region. These are principally wing shell, rock oysters, soft corals and gorgonians, hard corals and hydroids (URS 2006a).

The reef effect of submerged structures is believed by some to promote or increase the dominance of predatory species; however, this has not been adequately demonstrated. A biological monitoring study of the artificial reef, *HMAS Swan*, in Western Australia (Morrison 2001) found that a very large fish and encrusting invertebrate community had established over a four year period on a scuttled vessel in 30 m of water. During the first year the initial colonisation was dominated by prey species, but subsequently the presence of predatory species had stabilised with the community structure representing that of local natural reefs. Predatory species were not promoted above that of natural reefs and prey species appeared not to be any more vulnerable. The effect of the artificial reef was localised and the surrounding habitat was not affected.

Should submerged structures be removed during decommissioning, thereby removing the artificial habitat and associated communities, the overall environmental impact will be negligible compared to pre-installation levels and removal would lead to a return to original biota levels. Should the structures be left in place, the habitat associated with them would remain intact. Options to decommission facilities and consideration of the associated impacts will be thoroughly investigated well in advance of decommissioning and approval will be sought from the relevant regulators.

The presence of offshore infrastructure is highly unlikely to impact upon humpback whale migration routes and whale feeding areas as much of the infrastructure (for example, wellheads and manifolds) will be located on the seabed, whilst the offshore platform and risers do not represent large obstacles and can be avoided. Similarly no other EPBC Act listed species are likely to be impacted by the presence of offshore infrastructure.

The presence of the subsea gas trunkline has the potential to affect small scale hydrodynamic relationships within the Dampier Archipelago. For instance, where the gas trunkline will be laid above the seabed, it has the potential to affect sediment dynamics during tidal movements and cyclonic events, although impacts are expected to be slight.

The presence of a causeway at Holden Point has the potential to cause erosion and/or accretion of the shoreline by interrupting sediment transport patterns. The shoreline in the vicinity of Holden Point however, is generally rocky coast and not depositional beach, therefore sediment accumulation is expected to be negligible and the potential for erosion is limited.

Alteration of the nearshore wave regime due to the jetty and causeway could potentially affect the orientation of hatchling turtles, which can orientate themselves using the wave line; however, given the low nesting activity at the beach to the west of Site A and limited length of the causeway, potential impacts are likely to be slight.

Vessels: Vessel activity expected during the life of the Development is summarised in **Table 7-1**. The potential for collisions between marine mammals (for example, dolphins and whales) and vessels is considered slight given that these species are likely to exhibit behavioural and avoidance responses and the majority of vessels will be moving at restricted speeds within port limits in accordance with DPA requirements. In addition, the potential for collisions between dugongs and vessels is considered slight given vessels will not be moving through known dugong feeding areas. Risk to sea turtles is considered medium given the observed movements of flatback turtles through the Dampier Archipelago during inter-nesting and migratory periods (**Section 6.3.5**) and the subsequent increased chance of collision with vessels.

The presence of vessels operating in the northern area of Mermaid Sound and immediately to the north of Dampier Archipelago has the potential to interfere with humpback whale migration and female/calf resting areas (**Figure 6-16**). Adult humpback whales and their young frequent the Archipelago on their southern migration in early spring. Similarly, non-migratory whale species including Bryde's (*Balaeonptera edeni*) and Minke (*Balaenoptera acutostrata*) whales have been recorded in the Dampier Archipelago (CALM 2005). The passage of vessels through Mermaid Sound during construction and operations may coincide with these periods of humpback whale activity. During construction, dredge spoil disposal will be directed to a deep water spoil ground (2B) close to the entrance of Mermaid Sound and in the vicinity of the southerly migration path for humpback whales. Dredge vessels will be disposing of spoil into this spoil ground on an ongoing basis for approximately 20 months which will have the potential to disturb humpback whales especially in early spring. It is noted however, that whales do 'co-exist' with relatively high levels of shipping activity in Mermaid Sound. In 2004/2005 approximately 2000 vessels transited through the waters of Mermaid Sound (Worley Parsons 2005). The Pluto LNG Development will add an additional 1–2 ship movements per week during operations, which equates to approximately 5% increase on the current level of shipping activity.

Preventative and Management Measures

No specific measures are proposed to prevent or minimise the negligible effects of the artificial habitat created by the offshore and nearshore infrastructure. The creation of habitat due to the presence of subsea structures may result in a positive impact.

Measures to manage potential impacts on marine mammals and sea turtles are outlined in **Section 7.9.15** and include the development of a DSDMP to mitigate disturbance effects from dredging related activities within Dampier Archipelago and a Sea Turtle Management Plan. A Decommissioning Plan will be developed, and approval will be sought from the regulatory authority prior to commencement of decommissioning activities.

Residual Risks

With the implementation of the controls mentioned above the residual risks are considered low to medium as shown in **Table 7-2.**

Table 7-1 Development Related Vessel Activity

Vessel Type	Development Phase	Activity
Construction and Commissioning	Development Drilling	Semi-submersible drill rig at Pluto gas field
		Up to three anchor handling / supply vessels during rig movement operations
		Support vessels
	Platform Installation	Platform towed to site
		Platform installed on seabed
		Support vessels for platform installation
	Subsea Installations (Flowlines, Manifolds)	Subsea flowlines installed by specialist vessels
		Subsea manifold installation and hook-up by use of ROV
		Support vessels
	Trunkline Installation	Shallow water anchor spread type barge
		Deeper water (outside Mermaid Strait/ Mermaid Sound): either dynamically positioned ship or semi-submersible barge
		Pipe haul vessels or dumb barges towed by tugs to deliver pipe sections to site
		Refuelling / bunkering vessels
		Drill and blast rig for waters <5m and drill rig for NWSV shipping channel crossing
	Trunkline Stabilisation	Barge mounted backhoe dredge in waters <5m to remove fractured rock
		Trailer suction hopper dredge for trunkline trenching in nearshore and offshore waters
		Barge containing rock for trunkline stabilisation in nearshore waters
	Navigation Channel, Turning Basin, Berth Pocket	Barges for jetty installation
		2 x trailer suction hopper dredges operating between dredging location and spoil disposal grounds
		Cutter suction dredge operating between dredging location and spoil ground
Operation	Offshore - Pluto Gas Field Activities	Supply vessels servicing normally unmanned riser platform from shore base
		ROV inspections of subsea infrastructure
		Helicopter operations - transporting relief crew to rig
		Permanent platform support vessel
	Gas Trunkline	ROV inspections of trunkline
	Navigation Channel	Standby tugs
		LNG tankers (approx one every five days)
		Condensate tankers (approx one every three months)
		Maintenance dredging (as required)
		Supply vessels servicing offshore platform
Decomm	Offshore - Pluto Gas Field Activities	Vessels to remove subsea well heads and manifolds
		Vessels to remove flowlines and trunkline (if required)
		Vessels to remove platform to mudline
		Support vessels during decommissioning

Table 7-2 Summary of Impacts, Management and Risks of Physical Presence

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Physical Presence	Presence of jetty and causeway	Localised effects on hydrodynamic regime and sediment transport Potential disorientation of sea turtle hatchlings	Movement of vessels other than vessels with limited manoeuvrability (for example, tankers) will be conducted in accordance with the requirements of the EPBC Act and Regulations regarding maintenance and avoidance of marine mammals. Should any marine mammals or sea turtles be observed within 300 m of a vessel during dredging spoil disposal activities, disposal must be stopped and may not recommence until the animal/s are seen to move >300 m from the vessel or have not been spotted for >20 minutes. This will be undertaken in accordance with the DSDMP (**Appendix I**). A Sea Turtle Management Plan will be developed and implemented. A Decommissioning Plan will be developed, and approval sought from the regulatory authority, to undertake decommissioning of the facilities.	E	3	L
	Movement of Pluto LNG Development vessels	Collisions with marine mammals (dolphins, whales, dugongs)		E	2	L
		Collisions with sea turtles		D	3	M
	The offshore platform and associated legs/ moorings Manifolds and flowlines Trunkline Glycol supply line Marine discharge pipeline Standalone jetty and causeway	Subsea structures provide a habitat for marine fouling communities		E	0	L
		Disturbance to whale migration/feeding/ calving areas		C	2	M

7.5 Seabed Disturbance

Potential Impacts

The following activities will result in direct disturbance to the seabed during both the construction and/or operational stages of the Pluto LNG Development:

- drilling of wells at the Pluto gas field
- anchorage of a semi-submersible drilling rig (likely option)
- discharge of drill cuttings and muds (refer to **Section 7.8.1** and **Section 7.8.2**, respectively)
- installation of subsea wells, manifolds and flowlines
- installation of the platform including moorings
- directional drilling/dredging/trenching/blasting for the gas trunkline and marine discharge pipeline
- installation of the gas trunkline and glycol supply line
- construction and operation of a jetty adjacent to Site A
- dredging of a navigation channel including turning basin and berth pocket
- dredge spoil disposal.

Offshore – Pluto Gas Field: Seabed disturbance resulting from the drilling of wells, the installation and presence of wells, manifolds, flowlines, platform and offshore gas trunkline, will be localised. Given the limited footprint of the Development and broad regional representation of habitat in the Development area, significant impacts with respect to infauna and epifauna mortality and displacement are unlikely. Impacts associated with deposition of cuttings and muds from drilling are discussed in **Section 7.8.1** and **Section 7.8.2**, respectively. Seabed habitats in offshore and nearshore that may potentially be disturbed are discussed below.

A series of rock pinnacles that appear to be biogenic in origin and created by a deep water coral are located in approximately 300 m water depth and are considered noteworthy features. These pinnacle structures provide habitat for fish and invertebrates. Flowlines will be routed to avoid identified rock pinnacles, as far as practicable.

Trunkline – Nearshore: Laying of the trunkline, trenching and rock dumping (if required) will result in localised disturbance to benthic communities; however, given the absence of significant seabed features along most of the nearshore route, potential impacts in these areas are considered slight.

Sponge Communities, South-West of Legendre Island: The gas trunkline intersects two areas of the outer Dampier Archipelago, south-west of Legendre Island, classified on the CALM habitat map (CALM 2005) as being coral reef (sub-tidal reef platform). These low relief subtidal limestone reef platforms typically support a high diversity and density of sessile filter feeders including large sponges, sea-pens, sea-whips, gorgonian corals, soft corals, isolated hard corals and possibly macroalgal turf or bare pavement (Bancroft and Sheridan 2000). Surveys of the inner reef (north-west of Gidley Island) in 2005, revealed 10–20% gorgonian, soft coral and sponge cover but virtually no scleractinian corals (J Stoddart [MScience] pers comm. 10 November 2006). While there are no known surveys of the outer (deeper) site, surveys at the west of the entrance to Mermaid Sound, also classified as coral reef (sub-tidal reef platform) on the CALM habitat map (CALM 2005) showed similar benthos (that is, virtually no scleractinian corals). These two reef areas are likely to experience impacts from trenching, laying of the gas trunkline and trunkline stabilisation through an area approximately 1 km in length and 50 m wide, giving a total disturbed area of up to 0.05 km^2; plus potential for additional disturbance associated with anchoring. While it is not known if these sponge communities would re-establish on ground disturbed as a result of the installation of a buried trunkline, the CALM habitat map (CALM 2005) suggests that similar sponge community assemblages are widespread throughout the Dampier Archipelago and occupy approximately 50 km^2. The disturbance area is a small proportion of the regional representation of this habitat and represents approximately 0.1% of this habitat within the Dampier Archipelago

Potential impacts to sponge communities due to turbidity and sedimentation resulting from dredging for trunkline installation are discussed in **Section 7.9.7.10**.

Rocky Outcrop Supporting Coral, Holden Point: Gas trunkline Option 2 intersects a 10 m wide band of rocky outcrop supporting coral, adjacent to the shoreline at Holden Point near Site A (URS 2004b). Coral cover at this location is patchy and typical of Mermaid Sound, with monitoring reporting coral cover upto 15% (MScience 2006a). The main species recorded on the transects were *Goniastrea australensis* and *Platygyra sinensis*. Although the impact will be localised, impacts caused by direct removal of coral habitat from trenching, trunkline laying, rock dumping and dredging for a turning basin are expected to be major. Corals may potentially re-establish where the submerged parts of the causeway and the rock-stabilised trunkline provide suitable substrate, as has been observed on some anthropogenic structures elsewhere in Mermaid Sound. Further discussion on direct impact on corals at Holden Point with associated calculations of loss is provided in **Section 7.9.10**.

Impacts on corals, macroalgae and seagrass from turbidity and sedimentation associated with dredging are discussed in detail in **Section 7.9.10**.

General Effects on Biota: There is also potential for physical damage to coral from anchors and anchor wires deployed by the trunkline laybarge. As it moves along the gas trunkline route during pipe laying, the laybarge's anchors and anchor wires are positioned by a support vessel and can scour the seabed.

Each laybarge utilises 8–10 anchors with each anchor weighing 10–15 tonnes. Anchors typically drag 20 m before setting. Once the anchors are in position, movement will only be caused by the prevailing sea state and associated seabed damage will be minimal.

Anchors and anchor wires are designed for use on soft sediment and all efforts will be made to avoid deploying anchors and wires onto areas of hard substrate, including coral reef and sponge community assemblage areas (**Section 7.9.10**). Anchor wires have the potential to damage corals and sponges as they drop to and rise from the seabed with movements of the laybarge and tides. It is likely that the anchor wires (as opposed to the anchors themselves) will have more potential for physical disturbance to corals and sponges, should they be laid in sensitive areas, given the length of the wire that would be in contact with the seabed.

Previous Woodside experience with installation of the second trunkline for the NWSV found that impacts on corals resulting from anchors and anchor wires were slight. In a study undertaken by IRCE (2004b), areas 400–800 m east of the NWSV second trunkline route, corresponding to the distance at which anchors from the pipelay barge were routinely placed, were surveyed using ROVs. Twelve ROV dives were undertaken with damage to benthic biota observed during four dives. Less than 1% of the substrate surveyed during these four ROV dives was damaged with the observed damage limited to three toppled coral colonies and scraping of a rock outcrop. There were no long corridors of damage, which may be expected when long anchor wires (up to 800 m in length) are in contact with the seafloor. Nor was there any large scale impact which may be associated with the use of relatively large anchors. For example, no damage was observed on the extensive coral reef adjacent to Conzinc Island (400–600 m from the trunkline). It was concluded that the limited amount of damage was not likely to result in any effects to the ecological function of hard substrate habitats in Mermaid Sound and that the high quality of the geotechnical data obtained and subsequent careful placement of anchors was successful in limiting impacts on areas of hard substrate in Mermaid Sound.

It is therefore considered that, with appropriate management, impacts from anchors and wires on coral and sponge areas will be slight and will not contribute significantly to the areas of direct disturbance on sponge community assemblages as discussed previously. The effect of anchoring on areas of soft sediment is considered to be slight as the anchor and anchor line scars are expected to recover relatively quickly after the anchor has been removed. Similarly, the biological communities associated with these soft sediments are expected to recover quickly from such physical disturbance.

Potential impacts associated with the disposal of dredge spoil on the seabed at the proposed spoil ground(s) are likely but are considered slight given the existing benthic habitat (soft sediments), lack of epifauna and in the case of the existing spoil ground A/B in Mermaid Sound, the prior history of disturbance. Impacts associated with dredging are considered in **Section 7.9**.

Impacts on sponge community assemblages and coral reef areas from sedimentation and turbidity due to rock dumping will be localised and of short duration.

A buried glycol supply line will be laid adjacent to the gas trunkline and will result in only a very small increase in the disturbance footprint along the gas trunkline. Alternatively the MEG line could be piggy-backed to the trunkline.

Potential indirect impacts on sea turtles and marine mammals (including dugong, dolphins and whales) resulting from removal of habitat and feeding grounds (for example, seagrass and sponge communities) is considered unlikely given they represent only a small proportion of these habitats within the Dampier Archipelago. No direct disturbance to the seabed will occur in known areas of dugong feeding grounds.

Preventative and Management Measures

The management of seabed impacts will mainly involve adherence to appropriate procedures for installation of the platform, gas trunkline and coastal facilities, to ensure that seabed disturbance is minimised. Routing of flowlines and gas trunkline and locations of anchor points for the platform will avoid identified sensitive areas wherever possible, for example the deep water rock pinnacles. Barge anchoring procedures will be developed to guide the setting of anchors to minimise impacts on sensitive environments as far as practicable. It is anticipated that support vessels will only anchor in designated port areas unless they are involved in an emergency situation. Proposed management measures are summarised in **Table 7-3**.

Residual Risks

Residual risks resulting from seabed disturbance range from low to high as shown in **Table 7-3**.

Table 7-3 Summary of Impacts, Management and Risks of Seabed Disturbance

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Seabed Disturbance	Direct disturbance to seabed from installation of subsea wells, manifolds, flowlines, platform, moorings and gas trunkline (offshore)	Localised offshore seabed disturbance including mortality/ disturbance of benthos Impacts on rock pinnacles at 300 m depth	Routing flowlines and gas trunkline to avoid areas of sensitivities including rock pinnacles Siting of manifolds and platform moorings to avoid areas of sensitivities including rock pinnacles Vessels involved in installation of offshore subsea facilities will be equipped with bathymetry maps showing areas of sensitivities	E	3	L
	Trunkline laying, trenching and rock-dumping within Dampier Archipelago Construction of causeway, jetty and dredging for shipping channel and turning basin adjacent to Holden Point	Impacts on non-sensitive areas of Dampier Archipelago seabed	The final gas trunkline option will be routed to minimise disturbance to sensitive areas where practicable. Barge anchoring procedures will be developed for pipelay activities and will include: • accurate positioning of anchors to avoid or minimise impact to sensitive areas • identification and incorporation of areas of hard substrate including sponge community assemblages and coral reefs into a geo-referenced habitat map • prevention of anchor wire drag on the seabed by ensuring sufficient tension is maintained during anchor running operations Support vessels will not anchor outside designated anchoring areas unless in an emergency situation			L
		Direct mortality of corals adjacent to Holden Point				H
		Direct mortality of sponge communities south-west of Legendre Island in Mermaid Sound				H
		Mechanical disturbance to corals at Holden Point resulting from anchors and anchor wires				M
	Turbidity and sedimentation from rock dumping and backfill	Smothering of sponge communities and coral areas				L
	Dredge spoil disposal on spoil ground	Localised disturbance to the seabed due to a deep layer of disposed sediment				L

7.6 Beach Disturbance

Potential Impacts

Two nearshore gas trunkline options are currently under consideration and will include the following shore crossings:

- Gas trunkline Option 1 with a shore crossing at a small beach north of the NWSV Karratha Gas Plant.
- Gas trunkline Option 2 with a shore crossing at Holden Point, Site A.

Over the designated shore crossing length, that is, between the high water and low water marks, the construction method for both shore crossing options will be the same with a construction corridor up to approximately 50 m wide, plus an allowance for the placement of beach anchors.

Construction of the gas trunkline shore crossing will involve nearshore trench excavation and may include the installation of a temporary groyne which will be removed at the completion of the shore crossing. Subtidal and beach infaunal communities will re-establish rapidly and potential impacts are expected to be localised and slight. A glycol supply line will run next to the gas trunkline or piggy-backed and would result in only a very small, if any, increase in the disturbance footprint along the gas trunkline.

The key potential ecological impacts include disturbance to sea turtle nesting activity, seabirds, shorebirds and other shoreline and intertidal species. Other potential impacts include localised modifications to existing coastal processes, resulting from the placement of a temporary groyne during shore crossing construction activities.

Impacts to Sea Turtle Nesting Activity

Low density nesting effort by flatback and possibly green turtles has been recorded on the beaches at Holden Point (Site A) (Pendoley 2006). These survey findings may be considered representative of the nesting effort over the 2005/2006 breeding season. Sea turtle nesting at the beach to the north of the NWSV Karratha Gas Plant is considered very unlikely as this beach is completely inundated during high tides, making it unsuitable for sea turtle nesting. Potential impacts on sea turtle nesting and hatchlings at Holden Point beach are considered unlikely given the low intensity of nesting in the area. Additionally, blasting will be of a temporary and intermittent nature and will not be undertaken on Holden Point beach.

Artificial lighting associated with construction of the gas trunkline shore crossing, construction and operation of the gas processing plant at Site B and the storage and export facilities at Site A could result in the following potential impacts on sea turtles:

- Nesting attempts on the beach may decrease as females are deterred from emerging onto the beach due to lighting and disruptions (Witherington 1992).
- Hatchlings emerging from a nest may be disorientated from lighting. Hatchlings use light as a cue for ocean finding. They are attracted to artificial lights and will move towards these lights rather than the ocean.
- Hatchling exposure to predation may increase. Once in the water, hatchlings may also be trapped by the light spill from the jetty lights and concentrated within a small area exposing them to predation.

Given the low density nesting effort observed at the Holden Point beach and the limited duration and localised nature of construction activity, potential impacts on sea turtles are possible but are considered minor.

The other source of operational light with the potential to disorientate hatchlings from the beach adjacent to Site A is the flare relief system. This flare will however, only be used intermittently and will maintain a small continuous pilot light. There are a number of existing light sources in the vicinity of both Site A and Site B including the NWSV Karratha Gas Plant and DPA facilities. The light emitted from the operation of a small pilot light and intermittent flaring at Site A and Site B is anticipated to be relatively minor in comparison to existing sources. Given that flaring at Site A will be intermittent and that turtle nesting activity on the adjacent beach is considered to be low in relation to other turtle nesting beaches within the Dampier Archipelago and region, potential impacts are considered minor.

Impacts to Seabirds and Shorebirds

Potential impacts to seabirds and shorebirds from construction and operation activities include disorientation and attraction. During construction, potential impacts are likely to be slight given the limited duration of construction activities and the relatively low numbers of sea birds and shore birds utilising any of the proposed shore crossings for roosting and/or feeding. During operations, flaring activities at night have the potential to attract seabirds and shorebirds, although potential impacts are considered minor.

Impacts to Rocky Intertidal Areas

Trunkline installation and causeway and jetty construction will displace mobile epifauna on rocky intertidal areas at Holden Point. Given the disturbance area is a small proportion of the regional representation of this habitat, potential impacts are considered minor.

Impacts to Coastal Processes

Installation of a temporary groyne is likely to result in short term interruptions to the natural sediment transport regime in the immediate vicinity of the shore crossing. Given the hydrodynamic regime of the nearshore currents in the area and the timescale for this disturbance, it is unlikely that the presence of a groyne will significantly interrupt the natural transfer of sediments along the coastline. The temporary groyne is anticipated to result in slight impacts.

Preventative and Management Measures

Particular attention will be made to minimising the impact of construction activities on turtle nesting activities. A Sea Turtle Management Plan (**Table G-1**, **Appendix G**) will be developed and implemented during construction and operation phases.

The beach at Holden Point, Site A, will be monitored during the 2006 sea turtle nesting season (approximately December 2006 until April 2007) to assess the level of sea turtle nesting activity. Additional mitigation strategies will be developed, in consultation with the DEH and DEC, and included in the Sea Turtle Management Plan if monitoring results show there is significant turtle activity at the beach at Holden Point

Residual Risks

Residual risks resulting from beach disturbance are considered low as shown in **Table 7-4**.

7.7 Marine Pest Species

Potential Impacts

Introduced marine species are marine biota that are translocated into waters outside of their natural geographical distribution and subsequently settle and survive. Marine pests are introduced marine species that are of particular concern as they have the potential to cause significant ecological impact. The successful establishment of an introduced species depends primarily on two factors: the frequency of immigrant arrivals (introduction) and their post-arrival mortality (survival). Species are introduced primarily by one of three vectors:

- within vessel ballast water
- fouling, that is, attached to hulls and other vessel structures (for example, water intakes or sea chests and propeller shafts)
- within residual sediment on dredges and flotsam in the well around the cutter boom and head of cutter section dredges or ballast tanks.

The total number of introduced marine species within Australian waters has grown from 55 species recorded in 1990 to over 250 species recorded in 1999 (Hayes and Silva 2002). This number is likely to be higher because the taxonomic identification of certain species is unclear.

Table 7-4 Summary of Impacts, Management and Risks of Seabed Disturbance

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Beach Disturbance	Night time lighting along the export jetty during construction and operation Night time boundary fence lighting around Site A during operation Trunkline shore crossing construction	Disorientation of sea turtle hatchlings and reduced nesting attempts due to lighting	Monitoring of the beach at Holden Point, Site A, during the 2006 sea turtle nesting season (approximately December 2006 until April 2007) to assess the level of sea turtle nesting activity. Additional mitigation strategies will be developed, in consultation with the DEH and DEC, and included in the Sea Turtle Management Plan if monitoring results show there is significant turtle activity at the beach at Holden Point. A Sea Turtle Management Plan (**Table G-1**, **Appendix G**) will be developed and implemented, and include the following measures: • Minimise lighting to ALARP in nearshore areas while maintaining safe construction and operating conditions. • Minimising light spill, particularly where white lights, including fluorescent lights are used.	D	1	L
	Beach trench excavation	Disturbance of beach infaunal communities		E	5	L
	Temporary groyne	Interruption to coastal processes		E	2	L
	Construction activities and presence of humans	Impacts on roosting and/or feeding of seabirds and shorebirds		E	2	L
	Trunkline installation and causeway and jetty construction at Holden Point	Displacement of mobile epifauna on rocky intertidal areas at Holden Point		E	2	L

Introduced species can potentially have serious environmental impacts, including (Hass and Jones 1999):

- competition for food and space with native species
- predation of native species (including commercial species)
- possible hybridisation between native and introduced species.

Alternatively they can locate a vacant niche or habitat and have no negative impacts on the environment.

In Western Australia, 30 species of marine organisms are now recorded as introduced, the majority being crustaceans (Jones 1992; Hass and Jones 1999). Within Western Australian waters, few specific studies and surveys have been conducted to assess the distribution and assemblage of introduced marine species. The huge length of the coastline, the inadequate taxonomic understanding of many species and groups and the poor biotic lists for many aquatic habitats further exacerbate difficulties in recognising marine introductions (Hass and Jones 1999). There is no published data for Western Australia documenting any adverse impacts from introduced species on native species (Hass and Jones 1999). However, impacts have been documented for other Australian ports (for example, Port Phillip Bay, Victoria).

Potential impacts associated with the introduction and survival of invasive species into the Dampier Archipelago region and offshore Pluto gas field area, either by means of ballast water, hull attachment or dredge vessel residual sediment, are difficult to determine.

Carlton (1985) suggests that marine organisms contained within ballast water taken on in port or from hull fouling are likely to have specific habitat requirements and their distribution limited to sheltered habitats. Introduction of marine invasive species into the offshore waters in the vicinity of the Pluto gas field is likely to be restricted due to the lack of suitable habitat. Fouling communities on the platform may provide suitable habitat for introduced species, although the likelihood of survival, colonisation and spread will be limited. Existing environmental conditions at the proposed platform are not likely to be suitable for coastal species. Therefore, the introduction of pest species offshore is considered remote.

The platform will also be positioned in an isolated location, with low levels of shipping activity and should the establishment of an introduced species occur the likelihood of secondary transfer to the Pilbara coast or survival in coastal waters is considered remote.

No known pest species have been recorded within Dampier Archipelago which suggests that impacts are limited; however, no previous dedicated marine pest species surveys have been conducted within the Dampier Archipelago.

The potential introduction of invasive species into the Dampier Archipelago during construction and operations via ballast water is likely to be limited, given that high risk ballast water exchange will be conducted greater than 12 nm from the coast, in accordance with the Australian Quarantine and Inspection Service (AQIS) Ballast Water Management Requirements. Trading LNG and condensate tankers approaching the Dampier Archipelago, as well as support vessels for installation and construction activities, will exchange high risk ballast water prior to arrival, as required by Australian quarantine laws, greatly reducing the risk of introductions via ballast water. Hull fouling can greatly increase the fuel usage of vessels so the hulls of commercial vessels are cleaned on a regular basis and treated with anti-fouling paints. This also greatly reduces the likelihood of successful introductions from hull fouling. Finally, given that the likely export markets are located in temperate marine environments (Japan and North America) the likelihood of successful introductions into the tropical waters of the Dampier Archipelago is unlikely because of the different environmental requirements of temperate fauna.

Although species are known to have been previously introduced into the Dampier Archipelago from shipping activities, there is no record of adverse environmental impacts associated with these introductions, possibly reflecting the lack of studies. Potential impacts to nearshore waters are considered moderate.

Preventative and Management Measures

The focus of the environmental management of marine pest species will be on prevention of species introduction. Prevention measures are presented in **Table 7-5**. A Marine Pest Management Plan will be developed and implemented (**Table G-2**, **Appendix G**).

Residual Risks

The residual risk of marine pest species being introduced (via ballast water or as hull attachments) offshore in the Pluto gas field or along the offshore sections of the gas trunkline during installation, is considered low. However, the residual risk of introduction into the nearshore waters of the Dampier Archipelago is ranked as medium due to the proximity to shallow water and potentially suitable habitat.

Table 7-5 Summary of Impacts, Management and Risk of Marine Pest Species

<table>
<tr><th rowspan="2">Aspect</th><th rowspan="2">Activity, Event or Source</th><th rowspan="2">Affected Environment or Impact</th><th rowspan="2">Mitigation/Control Measure</th><th colspan="3">Residual Risk</th></tr>
<tr><th>C</th><th>L</th><th>RR</th></tr>
<tr><td>Introduction of marine invasive species into offshore waters (ballast water)</td><td>Vessels operating in the Pluto gas field (drill rig, supply vessels)</td><td rowspan="2">Competition for food and space with native species
Predation of native species (including commercial species)
Possible hybridisation between native and introduced species</td><td rowspan="2">A Marine Pest Management Plan (Table G-2, Appendix G) will be developed and implemented.
Application of the Quarantine Act 1908 and Regulations 2000 (Cwth) and the AQIS ballast water management requirements for international shipping (July 2001) will be compulsory for all vessels entering or leaving Australian waters. Where the potential risk is considered to be high, one or more of the following options for management of ballast water will be implemented:
• no discharge of ‘high risk’ ballast tanks in Australian waters
• tank-to-tank transfers
• full ballast water exchange at sea (that is, beyond 12 nm from the coastline).</td><td>D</td><td>1</td><td>L</td></tr>
<tr><td>Introduction of marine invasive species into nearshore waters (ballast water)</td><td>Vessels operating in the vicinity of the Dampier Archipelago (LNG and condensate export tankers)</td><td>C</td><td>2</td><td>M</td></tr>
<tr><td>Introduction of marine invasive species into offshore waters (hull attachment)</td><td>Vessels operating in the Pluto gas field (drill rig, supply vessels)</td><td rowspan="2">Competition for food and space with native species (particularly sessile species)
Predation of native species (including commercial species)
Possible hybridisation between native and introduced species</td><td rowspan="2">A Marine Pest Management Plan (Table G-2, Appendix G) will be developed and implemented.</td><td>D</td><td>0</td><td>L</td></tr>
<tr><td>Introduction of marine invasive species into nearshore waters (hull attachment)</td><td>Vessels operating in the vicinity of the Dampier Archipelago (including LNG and condensate export tankers)</td><td>C</td><td>2</td><td>M</td></tr>
<tr><td>Introduction of marine invasive species into nearshore waters (residual sediment and flotsam from dredge vessels)</td><td>Vessels operating in the vicinity of the Dampier Archipelago (dredge vessels)</td><td>Competition for food and space with native species (particularly sessile species)
Predation of native species (including commercial species)
Possible hybridisation between native and introduced species</td><td>Construction/installation vessels, including dredges, considered high risk with an overseas last port of call will be inspected prior to arriving on site.</td><td>C</td><td>2</td><td>M</td></tr>
</table>

7.8 Marine Discharges and Waste

7.8.1 Drill Cuttings

Potential Impacts

Drill cuttings are small fragments of rock removed from well holes during drilling, and are representative of the geological strata through which the well is being drilled. Cuttings will be discharged from individual well locations directly onto the seabed during drilling of the top hole well sections before the well is encased. They will also be discharged at the surface from the drilling of the lower sections of the well. Where cuttings are discharged to the seabed, a cuttings pile will develop immediately around the well site. The size of the pile will depend on a number of factors including tidal and current forces and water depth. The impacts of drill cuttings discharges on sediment properties and benthic communities are well documented. The United Kingdom Offshore Operators Association (UKOOA) sponsored an extensive initiative to assess the issue of cuttings piles in the North Sea from operations between 1970 and 2000 (UKOOA 2002). They have also been studied on the North West Shelf (Oliver and Fisher 1999).

Drill cuttings will also be generated during installation of the offshore platform legs. It is likely that a relatively small pile of cuttings will form around each of the platform legs.

Environmental impacts associated with the discharge of drill cuttings are likely to include:

- temporary increase in water column turbidity and limitations on light penetration through the photic zone
- potential smothering of benthic communities and alteration of sediment particle size
- decrease in oxygen concentrations in interstitial water (water in the sediment pore spaces).

Increase in Water Turbidity

Discharges of drill cuttings at the surface will result in the development of a plume of turbid water immediately around the discharge point however, this plume is likely to disperse rapidly and to be highly diluted, due to the relatively strong shelf currents that exist in the vicinity of the Pluto gas field. Given the short duration of drilling and the limited primary production of offshore waters, it is unlikely that light dependant phytoplankton will be affected by the temporary release of drilling cuttings into the water column. Potential impacts from water turbidity effects are therefore considered negligible.

Smothering of Benthic Species and Alteration of Sediment Particle Size

The discharge of drill cuttings to the seabed from drilling the top hole sections of each well represents the most significant source of smothering effects to benthic communities. Smothering of seabed species, with associated mortality, is likely to occur primarily through the clogging of respiratory and feeding apparatus. Studies undertaken by Det Norske Veritas (2000) indicate that immediately following discharge, the benthic community is eliminated under the discharged pile and is impoverished in the surrounding area (Wills 2000). Smothering of the seabed around individual wells is likely to be limited to areas where the cuttings pile is at least 5 mm in thickness, equivalent to 10 000 g/m^2. Post well inspections have found that the area affected typically extends 25 to 50 m radius from the well depending on the final well locations and any potential overlap (cumulative effect) in cuttings piles between neighbouring wells. Smothering constitutes a short-term impact that will be repeated across the field development, and benthic infauna and epifauna are known to recover relatively quickly. The low density and widespread distribution of benthic fauna at the Pluto gas field means that the impact to the benthic community will be slight.

The discharge of drill cuttings at the surface represents another potential source of smothering, with effects being, in part, dependent on the natural rate of sedimentation experienced as well as the tolerance level of species inhabiting the areas. The National Geophysical Data Center (NGDC) in the United States of America maintains a digital total sediment thickness database from which natural sedimentation rates for the North West Shelf can be estimated. An average sedimentation rate for the North West Shelf based on this database is 60 g/m^2/year. Given the deep water and the shelf currents encountered at the Pluto gas field, the surface cutting discharges are likely to disperse over a large area, resulting in very low benthic loads around the well site, and it is anticipated that maximum sedimentation loads forming around the well site from surface releases will be similar to the natural sedimentation rate for the area. It is unlikely therefore that the release of cuttings from the surface will result in significant impacts on benthic species.

The deposited drill cuttings (mainly from top hole cuttings) will alter the particle size distribution of the affected sediment substrate, altering the existing habitats within a localised area and having a possible influence on how fauna recolonise affected areas. In the short term, certain opportunistic species may potentially replace existing species, however, along with recruitment rates, the ability of the benthos to recover and recolonise will be influenced mainly by the effects on sediment and pore water chemistry (especially oxygen) that will occur after deposition of the cuttings.

De-Oxygenation of Sediments

The process of drilling will result in drill cuttings accumulating on top of each other from the top hole sections of each well. The top layers of the cuttings pile, present immediately around the well, will prevent oxygen and other seawater constituents from penetrating to the layers below (UKOOA 2002). These top layers (oxygenated active surface layer) are where biodegradation processes are more likely to occur. Over time, the lack of oxygen within the deeper layers of these accumulations also means that biodegradation is much slower.

De-oxygenation of the sediments, driven by degradation of Non-Water Based Muds (NWBMs), is likely to be the main factor in determining potential impacts to benthic fauna. Given that the footprint of the cuttings pile will mostly be the result of top hole cuttings drilled with Water Based Muds (WBMs) and representing only 20% of the total well discharge, the area affected by cuttings pile formation and long term de-oxygenation of sediments is likely to be limited. Potential environmental impacts are therefore considered slight.

Preventative and Management Measures

Potential impacts associated with the discharge of drill cuttings are likely to be limited by a number of inherent mitigation measures and factors:

- The deep water and relatively strong currents in the Pluto gas field will disperse drill cuttings over time, limiting the potential for longer-term cuttings pile formation. It is likely that the discharge of surface cuttings (representing approximately 80% of total individual well cuttings) will form a very thin layer on the seabed, similar to natural sedimentation rates. The remaining 20% of total individual well cuttings will be from seabed discharges and will form a cuttings pile immediately around the well.
- The benthic communities encountered at the Pluto gas field are generally representative of the region containing low abundance species (**Section 6**).

The mitigation and management measures are presented in **Table 7-6**.

Residual Risks

Drilling procedures have been continuously refined over a number of years to avoid and minimise environmental impacts to ALARP. As a consequence, impacts from the discharge of drill cuttings on water column turbidity and effects of smothering, oxygen depletion and the contamination of drill cuttings is assessed as likely and the potential environmental impact as slight.

7.8.2 Drilling Muds

Potential Impacts

There are two broad groups of drilling muds currently in use in Australia, namely WBMs and NWBMs. Over 80% of Western Australian offshore wells have been drilled using WBMs for all hole sections (Cobby and Craddock 1999). The top sections of each well are typically drilled with a WBM containing various additives, with the muds discharged into the marine environment at the completion of drilling. As the well becomes progressively deeper, the performance requirements of the drilling mud increase, needing higher performance NWBMs. For the deeper well sections, NWBMs will be used to lubricate the drill bit and will be returned to the surface along with the cuttings for treatment and re-circulation. Residual NWBMs on cuttings is minimised by the use of shale shakers and centrifuges.

Water based muds consist of water or brine solution mixed with bentonite clay and barite. Other substances are also added to gain the desired drilling properties including thinners (for example, lignosul-phonate), filtration control agents (for example, polymers such as carboxymethyl cellulose or starch) and lubrication agents (for example, polyglycols). Drilling muds also contain chemical additives used to control bacteria

Table 7-6 Summary of Impacts, Management and Risks of Drill Cutting Discharges

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Drill cuttings suspended in the water column (turbidity)	Development drilling	Decrease in water quality through localised increase in turbidity Localised effects on phytoplankton Disturbance to marine flora and fauna	The currents and depth of water in the vicinity of the Pluto gas field are likely to disperse the surface release of drill cuttings (refer to **Section 6.2.2**). This will minimise the effects of localised turbidity increases. Control measures detailed in a drilling Environment Plan (EP) will be developed and approved by the WA DoIR.	E	5	L
Drill cuttings smothering the seabed and altering sediment morphology	Development drilling and platform installation	Mortality or disturbance to benthic species and habitats Localised alteration of seabed morphology (cuttings piles) Reduction of oxygen transfer to underlying sediments	Formation of cuttings piles around the well head will be limited to cuttings discharged to the seabed from individual wells (representing only 20% of the total individual well cuttings volume) and piles drilled for platform legs. Cuttings discharged from the surface will disperse over a large area forming only a very thin layer of sediments on the seabed, which is unlikely to result in environmental effects. Drilling will not be undertaken in, or close to, sensitive seabed habitat. Control measures detailed in a drilling Environment Plan (EP) will be developed and approved by the WA DoIR.	E	5	L

formation and provide corrosion control whilst fulfilling other desired fluid characteristics. Non-water based mud is similar to WBM, but differs in terms of the base fluid which comprises a non-water based fluid (for example, esters or olefins), instead of seawater.

The main environmental impacts of drilling muds within the marine environment relate to chemical effects caused by toxicity, organic enrichment and the creation of anaerobic conditions (Neff et al. 2000). The initial physical impacts on benthic species and habitats from smothering effects will be substituted in the longer term by the toxicity effects of drilling muds.

Alteration of Sediment Characteristics and Biodegradability

Drill cuttings provide a mechanism by which drill muds can reach the seabed. Because NWBMs are immiscible in water, the NWBMs coated cuttings typically clump together, creating heavier agglomerations that settle more rapidly than cuttings with adhered WBMs. The depth of the receiving water will have an affect on the dilution and dispersion of the drilling muds as they undergo fractionalisation upon discharge. The larger and denser particles are likely to settle quickly, while the smaller and less dense particles will be suspended for longer periods of time (Neff 1987).

Recent studies have shown that in deep water more than 90% of NWBMs base fluid adhered to cuttings is lost as the particles fall through the water column (Nedwed et al. 2006). The loss of NWBMs base fluid and the dispersion of cuttings as they travel through the water column will result in a widespread distribution of cuttings with low concentration of adhered NWBMs.

Given that NWBMs are biodegradable organic compounds, their presence within the cuttings on the seabed increases the oxygen demand in the sediments. However, the low concentration and wide spread, low levels of sedimentation makes the deoxygenation of sediments unlikely.

Toxicity Effects

Both NWBMs and WBMs contain known chemicals that elicit toxic response (Atema et al. 1982). Acute toxicity testing is commonly applied to predict the toxic effects of drilling muds within the marine environment, and a number of studies have been conducted in the past to determine the exposure levels at which certain marine species experience such effects, such as Hinwood et al. (1994). The common LC50 (that is, the concentration of a chemical that kills 50% of a sample population) classification grades used to determine toxicity effects in marine species are presented in **Table 7-7**.

The toxicity of drilling muds used in drilling operations in Australian waters range from slightly toxic to non-toxic, depending on the test organisms used (APPEA 1998). The Western Australian DoIR generally considers the acceptable range for drilling muds to be slightly toxic to non-toxic. Non-water based muds including Olefin based mud are generally rated as non-toxic (96 hr LC50>100 000 ppm) to almost non-toxic (96 hr LC50 10 000–100 000 ppm) (ERM Mitchell McCotter 1997). The relatively low toxicity of NWBMs can be attributed to the fact that they contain low to negligible concentrations of aromatic hydrocarbons (<0.001% w/w – weight for weight), however, certain NWBMs still contain 30% w/w non-aromatic hydrocarbons and concerns therefore still remain over their environmental performance (ERM Mitchell McCotter 1997). Furthermore, NWBMs would not be introduced into the marine environment surrounding the Pluto gas field at concentrations approaching the levels required to elicit toxic response.

WBMs are generally less toxic than their NWBM counterparts, and are less likely to have any toxicological impacts. Should NWBMs adhered to drill cuttings form around well sites at sufficient concentrations to induce toxicological effects, the area of seabed and associated species composition affected is likely to be limited. In addition, not all species will be affected as certain species are likely to be more robust to toxicological effects. Over the longer term, disturbed areas will be re-colonised by biological communities. Experience from previous field experiments on the North West Shelf (Bakke et al. 1985) indicates that a seabed covered with 10 mm deposited cuttings and WBM was immediately re-colonised by algae, meiofauna and macrofauna. Similarly, an environmental survey conducted by Woodside to assess the environmental effects of drilling on the North West Shelf demonstrated little residual environmental effect remaining after three years (Woodside 2002). Potential environmental effects are considered slight.

Table 7-7 Classification of Toxicity Grades

Toxicity Rating	LC50 Value (mg/l)
Very toxic	<1
Toxic	1–100
Moderately Toxic	100–1000
Slightly Toxic	1000–10 000
Almost non-toxic	10 000–100 000
Non-toxic	>100 000

Source: Hindwood et al. 1994 contained in APPEA 1998

Non Routine Spills of Drilling Mud

Potential spills of drilling mud are unlikely to have a significant impact on the marine environment. Materials from a spill of drilling mud, which is of very low inherent toxicity, are likely to disperse in the water column or on contact with the seabed. Should drilling muds sink to the seabed they are likely to be dispersed rapidly through re-suspension into the water column and are unlikely to accumulate in sufficient concentration to affect benthic habitats. Potential impacts are considered slight.

Preventative and Management Measures

Preventative and management measures are presented in **Table 7-8**.

Residual Risks

For the discharge of drilling mud, the likelihood of residual impacts resulting from turbidity is considered likely and the corresponding environmental impact is slight. The residual environmental impact is therefore considered low.

The likelihood of alteration to sediment characteristics and toxicity effects from contamination is considered possible. The predicted environmental impacts are considered slight and the residual environmental impact is considered low.

Residual impacts from non-routine spills of drilling muds are highly unlikely given the preventative measures that will be in place, combined with the low probability of such events occurring. The predicted environmental impact is therefore considered highly unlikely and the residual environmental risk is low.

Table 7-8 Summary of Impacts, Management and Risks of Drilling Mud Discharges

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Drilling muds suspended in the water column	Development drilling (surface and seabed releases)	Decrease in water quality through localised increase in turbidity Localised effects on phytoplankton Disturbance to marine flora and fauna	The currents and water depth in the vicinity of the Pluto gas field are likely to disperse the surface release of drill cuttings (refer to **Section 6.2.2**) This will minimise the effects of localised turbidity increases. The Pluto gas field is likely to contain a low abundance of marine flora and fauna within the water column. Control measures detailed in a drilling Environment Plan (EP) will be developed and approved by the WA DoIR.	E	5	L
Drilling muds altering sediment characteristics (biodegradability)	Development drilling (surface release)	Increase in sediment oxygen demand Alteration of benthic habitat community structure		E	2	L
Toxicity effects from contaminated drilling mud discharge	Development drilling (surface release)	Bioaccumulation of chemicals and trace metals in species / food chain Mortality of species and communities from contamination Alteration of benthic habitat community structur	NWBMs will be re-used and recycled. NWBMs are generally rated as non-toxic to almost non-toxic. Cuttings potentially contaminated with NWBMs will be treated to ensure minimum risk to the environment. Specifications for treatment of cuttings will be defined within the Drilling EP based on an evaluation of the specific fluids to be used and conformance with DoIR requirements. NWBMs will only be used where WBMs cannot provide the required specifications (e.g. lubricity, bore stability). Control measures detailed in a drilling Environment Plan (EP) will be developed and approved by the WA DoIR.	E	2	L
Non routine spill of drilling muds	Development drilling (surface release)	Localised effects on plankton and fish	Transfer of drilling mud between the support vessel and drilling rig will be in accordance with an EP which will contain requirements for drilling mud transfers specific to the drill rigs and vessel selected. Control measures detailed in a drilling Environment Plan (EP) will be developed and approved by the WA DoIR.	D	1	L

7.8.3 Sludges and Sand

Potential Impacts

Small quantities of sludges and sand containing hydrocarbons may be bought up to the offshore platform and drilling rig periodically, for example during well clean up.

Sludges and sand will be stored offshore and then transported onshore for treatment or disposal at an approved facility, unless approval can be gained to dispose of material overboard. Disposal overboard will occur if approval is gained from the regulatory authority (either as part of an accepted plan or as a specific approval), and will not occur if sands or sludges are unacceptable for discharge.

Preventative and Management Measures

Management measures are summarised in **Table 7-9**.

Residual Risks

The implementation of the management measures summarised in **Table 7-9** will reduce residual risks to a low level.

Table 7-9 Summary of Impacts, Management and Risks of Sludges and Sands

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Sludges and sands	Development drilling and operations	Decrease in water quality through localised increase in turbidity causing: • localised effects on phytoplankton • disturbance to marine biota.	Where practicable, sludges and sand will be minimised at source, by using sand consolidation resins and completion stacks. Sludges and sand will be stored offshore and then transported onshore for treatment or disposal at an approved facility, unless approval can be gained to dispose of material overboard. Disposal overboard will occur if approval is gained from the regulatory authority (either as part of an accepted plan or as a specific approval), and will not occur if sands or sludges are unacceptable for discharge.	D	1	L
		Build-up of sediments on sea floor causing: • smothering of benthic communities and alteration of sediment particle size • mortality or disturbance to benthic species and habitats • oxygen depletion causing mortality or stress to epifauna species assemblage • alteration of sediment chemistry due to anoxic layer • provision of anoxic habitat for species.		D	1	L

7.8.4 Well Completion and Subsea Fluids

Potential Impacts

Once a well has been drilled to the required depth, well completion is conducted to clean the wellbore, prevent blocking of the reservoir and to provide a conduit for the well to flow to the process facilities.

These operations may include the wellbore displacement, sand-face completion installation operations, and installation of the completion string. Where a WBM is used, the completion fluids may consist of brine, such as potassium chloride (KCl) solution. Should NWBMs be used, the NWBM will be displaced from the well and replaced with brine prior to well completion. The brines are designed to minimise formation damage and provide the appropriate overbalance for well control. Typical brine formulations are anticipated to consist of sodium chloride (NaCl), KCl or calcium chloride ($CaCl_2$) salts. Final brine formulations will be based upon the resulting outcomes of formation damage testing and brine compatibility tests. The completion brine additives will be selected with bias to minimising environmental impact and meeting regulatory requirements for overboard discharge.

During well clean up, a low weight fluid (such as diesel) may be displaced into the completion string to allow the well to flow. This fluid will not be discharged but will be flared from the mobile offshore drilling unit.

The emission of greenhouse gases associated with well clean up represents only a small contribution to total emissions. Impacts from well completion fluids are not considered further.

A water-based subsea control fluid may also be used to control wellhead valves remotely. This is likely to operate on an open-loop system, with small amounts of control fluid discharged from the wellhead valves on the seabed when they are operated. Typically, volumes of approximately 6–20 l of control fluid will be discharged during each event (that is valve operation), which equates to an estimated 30 m^3/year of water-based subsea control fluid.

Open loop subsea control systems are an industry standard. The main properties required of a control fluid are: low viscosity, low compressibility, corrosion protection, resistance to microbiological attack, compatibility with seawater and biodegradability. The proprietary brand that will be used is not yet known, but the majority of subsea control fluids are freshwater-based with additives of MEG (typically about 40%), lubricants, other corrosion inhibitors, biocides and surfactant.

Subsea control fluids used will have been tested under the Oslo-Paris Commission (OSPARCOM) Harmonised Offshore Chemical Notification Format (HOCNF) to determine the potential of each component of a product to bioaccumulate and biodegrade in the environment. Toxicity tests are chosen in accordance with the expected fate of the materials. Based on the results of these tests the HOCNF classification for various water-based subsea control fluids is Group E meaning that it is in the group of least environmental concern. Up to 1000 tonnes may be released per annum from a single facility without prior notification to government bodies. Given the low inherent toxicity volumes discharged during each event and dispersion on release, the potential impacts of this discharge on the benthic community at the Pluto gas field are expected to be very localised and slight.

Preventative and Management Measures

Fluids with low toxicity (for example, MEG) will be preferably selected, subject to meeting operational requirements. Management measures are summarised in **Table 7-10**.

Residual Risks

Residual risks are considered low as shown in **Table 7-10**.

Table 7-10 Summary of Impacts, Management and Risks of Well Completion and Subsea Fluids

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Completions	Discharge of brine solution	Impacts on water quality	Low toxicity brine solutions selected.	E	5	L
Subsea fluids	Use of subsea control fluids	Toxicity to biota	Selection of fluids with low toxicity and high biodegradability. Minimal volumes to be used.	E	5	L

7.8.5 Deck Drainage

Potential Impacts

The offshore drill unit, platform, drilling rigs and Development vessels will have deck drainage consisting mainly of clean rainwater, which will generally be directed overboard. During drilling, well intervention or maintenance work, oily or dirty equipment may lead to the generation of contaminated drainage waste. The unintentional release of contaminated water from the decks of the offshore platform and Development vessels could lead to a reduction in water quality and an adverse impact on marine fauna in the immediate vicinity of the release. Without management measures, potential impacts are considered minor but quite likely to occur, however, management measures will ensure minimal contaminated discharge.

Preventative and Management Measures

The focus of Woodside's management will be to prevent contaminated waste being discharged via the vessels' deck drainage systems. The primary management measure will be to avoid the possibility of spills in the first instance, through selection of equipment and management processes. Materials handling and operating and maintenance procedures will also be implemented, and routine maintenance and visual monitoring will allow for the early detection of leaks, ensuring a quick response to effect repairs and clean up spills.

The management and preventative measures proposed are outlined in **Table 7-11**.

Residual Risks

The implementation of the management measures summarised in **Table 7-11** will reduce the likelihood of impact to water quality. Residual risks are therefore considered low.

7.8.6 Hydrotest Water

Potential Impacts

To allow hydrostatic testing to be undertaken (to test for leaks), the gas trunkline, flowlines and offshore/ nearshore pipelines will be flooded using seawater containing additives of corrosion, oxygen and scale inhibitors, biocides and fluorescent dye for leak detection. An estimated 153 000 m^3 of hydrotest water may be introduced into the gas trunkline alone. Hydrotest water from the flowline and gas trunkline will be disposed of into offshore waters – most likely from the platform – although consideration is also been given to discharge on or near the seabed.

The hydrotest water will be treated with oxygen scavenger to remove oxygen and thereby reduce potential for corrosion; consequently, on release the hydrotest water will be very low or lacking in oxygen. The main potential impact from its discharge is therefore oxygen deprivation of biota exposed to the de-oxygenated plume of water until it has mixed sufficiently with seawater. It can also affect existing water quality by the introduction of residual chemicals.

Normally, the biocides selected degrade gradually over time while the hydrotest water is kept in the trunkline (up to 12–18 months is expected) and then rapidly degrade on discharge and introduction to an aerobic environment, resulting in minimal environmental impact. The additives in the hydrotest water will be in a diluted form, and when discharged to sea will be further rapidly diluted to extremely low concentrations that are predicted to be harmless to marine communities in the area. Following hydrotest, residual water in the trunkline, MEG return pipeline and flowlines is likely to be removed by flushing the trunkline with a slug of MEG contained between two pigs. The MEG is classed as readily degradable and is expected to dilute rapidly in the offshore environment, below levels that could cause harm to any aquatic organisms, outside of a localised mixing zone. Potential impacts of discharge to the offshore environment are considered to be minor. Final details of the constituents within the hydrotest water and the disposal method selected will be specified in an Environment Plan, which will require approval from the WA DoIR prior to hydrotest activities commencing.

Onshore storage tanks, vessels and piping will also require hydrotesting. Hydrotest water will be sourced from either seawater or potable water, depending on the availability of water and water quality required (for example, salt content). It is expected that volumes of hydrotest water will be minimised through re-use (for example, testing tanks sequentially). If chemical additives are required, they will be selected taking into consideration the best available environmental and technical solutions. Hydrotest water disposal will be undertaken in a controlled manner, to ensure the potential impacts are minimised.

Preventative and Management Measures

The management and preventative measures proposed are outlined in **Table 7-12**.

Residual Risks

The management measures summarised in **Table 7-12** will reduce the likelihood and consequence of impacts from hydrotest water. However, it is likely that water quality impacts will be experienced for a period of time. Residual risks for offshore discharge are considered medium.

Table 7-11 Summary of Impacts, Management and Risks of Deck Drainage

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Deck drainage	During drilling, well intervention or maintenance work, generation of contaminated drainage water may be unintentionally released from the decks of the offshore platform and vessels	Localised reduction in water quality from contaminated deck drainage	The avoidance of spills through the initial design integrity built into process and utility equipment, materials handling and operating and maintenance procedures. No contaminated waste will be intentionally discharged via deck washdown. Areas on vessels, drill rigs and the offshore platform where hazardous materials will be stored, including fuels, oils and lubricants, will be bunded, and directed to a sump (or similar) which is connected to an oily water separator. Drainage water with hydrocarbon concentration >15 ppm will be treated to reduce concentrations to below 15 ppm and discharged overboard as per MARPOL 73/78 (International Convention for the Prevention of Pollution from Ships) regulations for vessels and to P(SL)A regulations for the platform. Remaining hydrocarbons will be stored in suitable containers and transported to shore for treatment and/or disposal by a certified waste oil disposal contractor. If vessels do not have an oily water separator, wastes will be shipped to shore for treatment. Contaminated drainage on vessels, rigs and platform will be contained and diverted to the slops tank or sump, or will be mopped up to prevent overboard discharge. To achieve this, vessels, rigs and platform will have scupper plugs available to block overboard drains, and will have absorbent booms and clean-up materials readily available so that any spill on deck can be rapidly contained. Drip trays will be used to capture oily material. Spills on deck will be contained and diverted to the slops tank, sump or mopped up to prevent overboard discharge. Deck drainage on the condensate trading tankers will be managed to the International Maritime Organisation and Oil Companies International Marine Forum guidelines and the International Safety Guide for Oil Tankers and Terminals to prevent any discharge of oily water. Routine maintenance and monitoring will allow for early detection of leaks, ensuring a quick response to repair leaks and clean up spills.	D	1	L

Table 7-12 Summary of Impacts, Management and Risks of Hydrotest Fluids

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Hydrotest Water	Offshore discharge of hydrotest water containing additives/ chemicals including biocides, oxygen scavenger (for example, ammonium bisulphite) and translucent dye	Effects on biota and water quality resulting from oxygen deprivation and biocides	A Pipeline Flooding and Hydrotesting Procedure and a Pipeline Pre-commissioning Procedure will be developed. Prior to its implementation, an environmental plan covering flooding, hydrotesting and pre-commissioning activities will be submitted to the regulatory authority for review and approval. Chemicals used as inputs into the hydrotest water will be chosen to ensure that the best environmental and technical solutions are achieved for the Development. The concentrations of the chemical additives in hydrotest fluids will be carefully determined. For example, only sufficient additives will be added to remove the oxygen normally present in the volume of seawater needed. Similarly, sufficient biocide is generally added to kill the bacteria in the filtered seawater without overdosing. Pre-commissioning systems offsite with appropriate hydrotest water treatment or recycling facilities will reduce the amount of hydrostatic testing required on site.	D	5	M

7.8.7 Anti-Fouling

Potential Impacts

Tributyltin (TBT) has in the past been the most common anti-fouling system on ships. In November 1999, the IMO directed the Marine Environment Protection Committee to develop an instrument, legally binding throughout the world, to address the harmful effects of anti-fouling systems used on ships, with the objective of instituting a global ban on the application of TBT paints by 1 January 2003, and a complete prohibition by 1 January 2008. The five year gap allows for ships legally coated with TBT prior to 1 January 2003 to operate until their next dry-docking for maintenance.

These conditions apply to all potential Development vessels, including the drill rig, pipe haul vessels, trading tankers, support and supply boats. The offshore platform will be newly constructed in accordance with the IMO regulations and will not be coated with any TBT anti-fouling. Neither the trunkline nor other associated subsea structures will have anti-fouling.

There is a possibility that some vessels to be used for the Pluto LNG Development are currently coated with TBT anti-fouling if they were last dry docked prior to 1 January 2003. Given the complete prohibition on the presence of TBT paints on ships by 1 January 2008, and the fact that construction and operation vessels are unlikely to be active before that date, it is unlikely any vessel in use on the Pluto LNG Development will have TBT anti-fouling. Potential impacts from TBT in anti-fouling paint are therefore considered remote.

With the global ban on TBT in anti-fouling paints, safer alternative substances (for example, copper based paints) will be considered. However, the nature of anti-foulant is such that it can potentially have harmful effects, not only on the fouling organisms they are designed to deter, but also on other marine life. There is evidence to show that certain species of fish and other marine organisms are sensitive to quite low levels of copper, even though other species are relatively tolerant of much higher levels. Marine invertebrates are thought to be slightly more sensitive to copper than fish (UK Marine Special Areas of Conservation 2006); however, given the strength of currents and depth of water through most of the Pluto LNG Development area, impacts on biota from alternative anti-fouling substances are considered slight (and are lower in comparison to TBT).

Preventative and Management Measures

Anti-foulants with the overall lowest health, safety and environmental risks that meet technical integrity requirements will be used. Management measures are summarised in **Table 7-13**.

Residual Risks

Residual risks from anti-fouling are considered low as shown in **Table 7-13**.

Table 7-13 Summary of Impacts, Management and Risks of Anti-Fouling

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Anti-fouling	Use of TBT	Toxic effects on marine biota	Construction and/or operation vessels to adhere to complete prohibition on the presence of TBT paints on ships by 1 January 2008.	C	0	L
	Consideration of alternative anti-fouling agents	Toxic effects on marine biota	Selection of chemicals with the lowest health, safety and environmental risks while meeting technical requirements.	E	3	L

7.8.8 Ballast Water

Potential Impacts

Ballast water is described in **Section 5.2.13**. The discharge of oil contaminated ballast water will not occur because vessels will be required to have dedicated fuel tanks or other holding areas that will not be used to hold ballast water. The potential for introduced marine species in ballast water is separately assessed in **Section 7-7**.

Preventative and Management Measures

Woodside has in place a tanker vetting system that will be applied throughout the Pluto LNG Development to ensure that tankers are of an acceptable standard.

Management measures are outlined in **Table 7-14**.

Residual Risks

Residual risks from ballast water are considered low.

7.8.9 Solid Waste

Potential Impacts

Marine impacts from non-hazardous solid wastes are expected to be negligible. Solid waste will be generated offshore during all stages of the Development, and the majority is likely to be transported back to shore for appropriate disposal or recycling.

The environmental impact of discarding non-hazardous, macerated putrescible (food) waste on the marine environment is expected to represent a small incremental addition to impacts associated with existing offshore waste disposal facilities located on the North West Shelf. The impacts are expected to represent a negligible to slight increase in the environmental impact associated with existing offshore activities.

Preventative and Management Measures

Effective waste management practices will be implemented during all phases of the proposed Development both by contractors and by Woodside's own support services, to prevent environmental impacts to the marine ecosystem. Each major contractor will be responsible for developing and implementing a waste management plan consistent with the management measures contained within a framework Waste Management Plan (**Table G-4**, **Appendix G**), as outlined in **Table 7-15**.

Residual Risks

Risks associated with solid waste generated from the Pluto LNG Development are manageable and are considered low.

Table 7-14 Summary of Impacts, Management and Risks of Ballast Water

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Ballast water	Contaminants in discharge of ballast water	Adverse impacts on the marine environment	Tankers will be of an acceptable standard. Vessels must have dedicated ballast tanks; fuel tanks or other holding areas must not be used to hold ballast water. The use of fully segregated ballast water tanks is a requirement of the vetting process; vessels that do not satisfy this requirement are not permitted. The same standard will be applied to all vessels. All vessels will comply with MARPOL regulations.	D	1	L

Table 7-15 Summary of Impacts, Management and Risks of Solid Waste

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Non-hazardous waste stream	Generation, storage and transport of general non-hazardous waste	Attraction of pest species	All domestic waste will be stored in clearly marked skips and waste containers will be provided on all vessels. Food waste from vessels will be macerated and discharged to the marine environment when outside of the 12 nm zone. Within that zone food waste will either be disposed of in general waste bins, which will be transferred onshore for disposal, or macerated and held in tanks until the vessel is beyond the 12 nm boundary. No other solid wastes will be discharged to the marine environment. Food wastes, sewage and grey water from drilling rigs and platforms will be, as a minimum, passed through a grinder or comminuter so that the final product will pass through a screen <25 mm diameter prior to disposal to the sea at a distance greater than 3 nm from land. Each major contractor will be responsible for developing and implementing a waste management plan consistent with the management measures contained within the Waste Management Plan (**Table G-4**, **Appendix G**). Options for recycling will be investigated and recyclable wastes will be segregated from other waste and stored appropriately. Waste reduction at source in tenders for supply and construction contractors.	E	2	L
		Generation of odours		E	2	L
		Reduction in water quality		E	2	L

7.8.10 Hazardous Waste

Potential Impacts

The volumes of hazardous waste generated offshore throughout all Pluto LNG Development phases are likely to be minimal. Oils and greases generated by the operation of machinery onboard vessels have the potential to cause adverse environmental impacts if accidentally lost to the marine environment in large amounts. The drill rig and offshore platform represent the main sources of hazardous waste.

As no hazardous waste will be disposed to the marine environment, potential affects to environmental receptors are considered negligible.

Preventative and Management Measures

A number of controls will be implemented to ensure the safe management of hazardous wastes, to prevent impacts to the marine environment and prevent hazards to personnel (**Table 7-16**). Each major contractor will be responsible for developing and implementing a waste management plan consistent with the management measures contained within the framework Waste Management Plan (**Table G-4**, **Appendix G**).

Residual Risks

Risks associated with hazardous waste vary according to the nature, volume and type of hazard exhibited by the waste. In all cases, the sound management methods outlined in **Table 7-16** will reduce the level of risk to low.

Table 7-16 Summary of Impacts, Management and Risks of Hazardous Waste

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Hazardous wastes	Generation of hazardous wastes offshore during construction, operation and decommissioning	Impacts on water quality and marine biota	The drill rig will recover oils where possible, particularly from slops, for recycling in the crude oil process/ oily water separator. If required, recovered oils will be shipped to shore for processing. Sump oils from diesel engines used to power cranes, generators, compressors and other machinery will be collected and stored in containers for transport back to shore for recycling. All hazardous waste materials will be documented and tracked, segregated from other waste streams and stored in suitable containers. All hazardous waste will be transported to shore for appropriate disposal or recycling at an approved facility in accordance with regulatory requirements. Hazardous waste storage facilities and handling equipment will be segregated, kept in good order and designed in such a way as to prevent and contain spills. Transfer of hazardous material between the platform and supply vessels and the drill rig and supply vessels will be conducted in accordance with the defined procedures that will be identified to all personnel concerned with transfer operations. Each major contractor will be responsible for developing and implementing a waste management plan consistent with the management measures contained within a Waste Management Plan (**Table G-4**, **Appendix G**).	E	1	L

7.8.11 Naturally Occurring Radioactive Material

Potential Impacts

The produced water contained within the Pluto reservoirs may contain minimal quantities of Naturally Occurring Radioactive Materials (NORMS). Under certain conditions (high salinity, together with the presence of sulphates and/or carbonates, calcium, barium and strontium) NORMS can become bound to scale deposits forming in piping (including the gas trunkline) and process vessels.

Maintenance of vessels during production phase and clean-up tasks during decommissioning may require the disposal of scale if it has built up as a solid in the flowlines and pipework over the life of the Development.

Potential environmental effects associated with the disposal of NORMS to the marine environment include toxicity effects on marine flora and fauna. Given that there is an extremely low risk of NORMS being encountered at the Pluto gas field and that NORMS, if encountered would be directed to sea in extremely low volumes into the marine environment, potential impacts are considered negligible.

Preventative and Management Measures

The build up of scale, and hence accumulation of NORMS, will be controlled with the use of appropriate scale inhibitor. Preventative and management measures are outlined in **Table 7-17**.

Residual Risks

Due to the low potential for the generation of NORMS at the Pluto LNG Development, residual risks requiring management are relatively limited (**Table 7-17**).

Table 7-17 Summary of Impacts, Management and Risks of NORMS

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Generation of NORMS	Accumulation of scale in process and pipeworks	Toxicity effects on marine flora and fauna	Management and disposal of NORMS in accordance with the APPEA 2002 guidelines '*Guidelines for Naturally Occurring Radioactive Materials, Australian Petroleum Production and Exploration Association Limited, Canberra*.' Use of an appropriate scale inhibitor to control build-up of scale (and therefore NORMS). The disposal and management of NORMS during decommissioning will be subject to a regulatory approved plan.	D	1	L

7.8.12 Cooling Water

Potential Impacts

While on site for drilling and installation activities, the drill rig will require cooling water to prevent over-heating of machinery. For this purpose seawater drawn from the ocean will be circulated through heat exchangers and then discharged back into the ocean. Seawater may also be required on the offshore platform for cooling of wellstream fluids, process equipment, fire protection systems and freshwater production. As the cooling system is segregated from other systems, the risk of cooling water contamination is very low; however potential impacts from the discharge of cooling water may result from temperature differences, or from biocides in the cooling water. Mixing and dispersion of the discharged cooling water will reduce the temperature of the water and the concentration of biocides added. Typical biocides include sodium hypochlorite (chlorine), most of which reacts within the cooling system. Dosing rates are controlled to minimise the available chlorine in the discharge, and in the marine environment the biocide rapidly degrades to salt. As pelagic species in the Pluto LNG Development area are mobile, any exposure to the discharged cooling water would be temporary, with the exception of the fouling species located near the discharge point. The ecological impacts of cooling water discharge offshore are expected to be negligible.

Preventative and Management Measures

Management measures are summarised in **Table 7-18**.

Residual Risks

Residual risks are shown in **Table 7-18**.

Table 7-18 Summary of Impacts, Management and Risks of Cooling Water

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Cooling water	Discharge of cooling water (offshore)	Reduction in water quality	The use and dosage of biocide in cooling water will be kept to the minimum required to ensure the cooling water system is in suitable condition for operational purposes. Rapid dispersion of the biocide by the surrounding ocean at the discharge point will also assist in minimising impacts.	E	5	L

7.8.13 Waste Water

7.8.13.1 Summary

Several waste water streams will be generated from offshore and onshore vessels and facilities. Waste water streams will include: produced water, sewage, grey water, non routine contaminated water, AOC water and demineralised water. These waste streams, if not managed correctly have the potential to result in pollution and nutrient enrichment of the surrounding waters.

All waste water from the onshore gas processing plant (Site B) and storage and export facilities (Site A) will be treated before discharge through a common discharge pipeline into Mermaid Sound at the seabed near the end of the export jetty (**Figure 4-11**). Details of the water treatment and discharge specifications for the waste water treatment facility are provided in **Section 5.2.15**.

7.8.13.2 Offshore Vessels and Facilities Waste Water

Potential Impacts and Management

Offshore sewage and grey water will be produced by vessels during construction and commissioning phases. During operations sewage and grey water will primarily be generated during maintenance of the riser platform as it would not necessarily be manned full-time.

Routine discharges from vessels, including grey water, food scraps and sewage will be managed in accordance with MARPOL 73/78 and *Protection of the Sea* (*Prevention of Pollution from Ships*) *Act 1983* (Cwth), and may cause a small, localised temporary increase in the nutrient content in the water column. Untreated sewage and food wastes may be discharged at distances greater then 12 nm from land. Sewage that has been comminuted and disinfected, in accordance with MARPOL 73/78 and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* may be discharged at distances greater then 3 nm from land. Sewage from a MARPOL 73/78 compliant sewage treatment plant may be discharged at any location providing the effluent does not produce visible floating solids nor cause discolouration of the surrounding water.

Sewage waste from the platform and drilling unit will, as a minimum, be passed through a grinder or comminuter so that the final product will pass through a screen <25 mm diameter prior to disposal to the sea at a distance greater than 3 nm from land.

Localised nutrient enrichment from the discharge of sewage and grey water into surrounding waters from any of these sources is unlikely to result in elevated nutrient levels, given that the platform, drilling unit and vessels will be located in open water where there is regular mixing of water through the water column and, in the case of vessels, sewage and grey water will be treated prior to disposal (**Section 5.2.15.1**).

No significant environmental impacts are expected because of the biodegradability of the waste, short period of activities and large dilution factor. Total nutrient (nitrogen and phosphorus) input levels will be insignificant compared with natural levels in most bodies of seawater. The potential for saprogenic effects resulting from decomposition of organic matter is considered slight. Toxicity effects tend to only occur when sewage and grey water are discharged in high volumes. It is likely that a relatively small amount of sewage will be discharged and hence toxicity effects to marine fauna will not be experienced.

7.8.13.3 Onshore Treated Waste Water

Potential Impacts

Summary: Waste water generated onshore will include sewage, grey water, non routine contaminated water, AOC water, demineralised water and produced water. The greatest volume of sewage and grey water will be generated during the construction and commissioning phases, with the greatest volumes of other waste water expected during operations.

All waste water from the onshore gas processing plant (Site B) and storage and export facilities (Site A) will be biotreated and further treated by polishing filters before discharge through a common discharge pipeline. Details of the water treatment and discharge specifications for the waste water treatment facility are provided in **Section 5.2.15**.

Sewage: Site B will contain a sewage treatment package comprising of a compartmentalised tank and air distribution system. The discharge of treated sewage and grey water from the onshore facilities into the nearshore waters through a marine discharge pipeline (if this treated waste water cannot be used for onsite reticulation) could result in slightly elevated nutrient levels within a small, localised mixing zone and could attract fish and other marine fauna. Similarly, nutrient enrichment in the nearshore waters could increase the growth of specific algal species including *Ulva* sp. and *Cladophora* sp. Factors that will determine the significance of the impact will include the end of pipe dispersion or diffuser technology adopted and tidal and current forces.

Non Routine contaminated water, AOC Water and Demineralised Water: Non routine contaminated water and AOC water will be collected via drainage systems and held in a central retention basin, from where it will be directed to an oil water separator unit, which is expected to be a combination of corrugated plate interceptor, dissolved air flotation unit and macroporous polymer extraction. The water will be treated and oil will be removed for recycling. Demineralised water will normally be circulated through the gas processing plant; however, if it is discharged, it will also be routed into the central retention basin before being treated in the waste water treatment plant.

As the Burrup Peninsula is subject to heavy rainfall events, typically associated with cyclones, the storm water management system will be designed to cope with high instantaneous flows. The gas processing plant will be sealed with a drainage management system to allow the segregation of clean water from potentially contaminated water, including AOC water, as described in **Section 5.2.15**. Accommodation facilities will not be established on-site but in Karratha and Dampier.

Produced Water: The treatment and discharge options for produced water from the Pluto LNG Development, comprising formation water and condensed water are discussed in **Section 5.2.15**. Produced water will be treated to achieve total oil in water concentration of less than 5 mg/l at the onshore gas processing plant and will be treated by macroporous polymer extraction, followed by biotreatment and final filtration/polishing. The treated commingled stream will be disposed of via a common discharge line into Mermaid Sound at the seabed near the seaward mooring dolphins of the export jetty (**Figure 7-5**); unless a preferable alternative is identified in future design phases, the process for which is discussed in **Section 3.6**. To prevent hydrate formation, a hydrate inhibitor (most likely MEG) will be injected into the gas trunkline at the platform in volumes approximately equal to formation water and condensed water volumes. The MEG, which dissolves into the formation water and condensed water, will be recovered at the onshore gas processing plant and returned to the platform. Trace quantities of MEG (concentrations up to approximately 100 mg/l) could be discharged with the produced water. For this reason the entire produced water stream will be biotreated and then filtered.

Fate and Environmental Effect of Treated Waste Water: Once discharged to the ocean, treated waste water will be subject to a number of physical, chemical and biological changes. Although the individual processes causing these changes act simultaneously, their relative importance varies with time. In the short term, dilution and evaporation are the most effective processes for reducing residual contaminant concentrations, mitigating the potential effects. Biodegradation, oxidation and sedimentation processes act over longer timeframes, reducing the potential for chronic impacts.

Prior to production, it is difficult to predict the exact composition or toxicity of treated Pluto LNG Development waste water, primarily because the composition and toxicity of the produced water is currently unknown and will not be determined until first water becomes available. However, based on knowledge of other produced water in the region and also worldwide, it is likely to contain trace concentrations of:

- petroleum hydrocarbons
- phenols
- organic acids
- metals
- residual process chemicals.

When produced water treated to offshore standards is discharged to the sea, the organic compounds within the formation water are distributed between water soluble and oil-droplet fractions (droplet sizes ranging from 1–10 μm in diameter). A variety of organic acids, phenols, BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) and two or three ring Polycyclic Aromatic Hydrocarbon (PAHs) compounds will dissolve completely or partly in the receiving waters, and will be dispersed by the ambient currents. These compounds are bio-available to marine organisms and will biodegrade within days, forming carbon dioxide and water. They are also volatile and will preferentially evaporate from the sea surface. They do not adsorb strongly to suspended particles and so are unlikely to be transported to the seabed. At its peak Pluto LNG Development waste water will be comprised of 1000 bpd of formation water.

Untreated condensed water is free of salts and contains some highly volatile hydrocarbons, such as BTEX, that have condensed from the gas as it is transported from the well to the platform and then to shore. At the Site B waste water treatment plant, all hydrocarbon droplets will be removed from the waste water prior to discharge. At its peak, Pluto LNG Development waste water will be comprised of 4000 bpd of condensed water.

Polycyclic Aromatic Hydrocarbons (PAHs) are the petroleum hydrocarbon of greatest environmental concern in untreated produced water. They have a wide range of solubilities (Neff 2002). Biodegradation half lives of PAHs range from readily to poorly biodegradable and vary from 1.5 days for naphthalene, 17 days for two to three ring PAHs and 350 days for more than four ring PAHs (Johnsen et al. 2000). All PAHs (with the exception of naphthalenes, which are readily biodegradable) have a strong tendency to bioaccumulate in the tissues of marine organisms (Neff and Sauer 1996). Solubility of PAHs decreases with increasing molecular weight so the most common PAHs in produced water are naphthalene, alkylnaphthalenes, fluorene and phenanthrene. These are predicted to be present in low initial concentrations (typically no greater than 1 mg/l and often much less) and, on discharge, will be reduced further by rapid dilution due to the diffuser, mixing with the receiving water and evaporation from the sea surface. The potential for bioaccumulation of PAHs is therefore limited and the risk considered low, especially given that the waste water treatment plant at Site B will remove essentially all PAHs.

Heavy metals associated with produced water are usually present at trace levels as dissolved mineral salts. Reservoir water is anoxic and the metal ions are typically in low oxidation states. However, when brought to the surface and exposed to the atmosphere they oxidise. The metals oxide then combine with anions such as sulphides, carbonates and chlorides and form insoluble precipitates. Dilution in the receiving environment will reduce metals contained in Pluto LNG Development treated waste water to background levels and well below chronic toxic thresholds. When they form precipitates, there is the potential for build up in the sediments, however, the quantity is so low and spread across the seabed so wide that the impact is insignificant. In the Site B waste water treatment plant, most heavy metals will be removed through biotreating and polishing filters.

Untreated produced water will also contain low levels of chemicals that have been added to the production process for purposes such as emulsion control, inhibiting scale formation, reducing corrosion and preventing growth of bacteria. These production chemicals are soluble in MEG to varying extents and are expected to remain in the MEG during regeneration, although a small proportion will ultimately be discharged with the produced water. The number of additives used in a particular production system is usually low and depends on the particular production problems encountered in the well. They could include:

- biocides
- corrosion inhibitors (including MEG)
- scale inhibitors
- oxygen scavengers
- demulsifiers
- emulsifiers
- coagulent/de-oiler
- flocculant
- antifoam agent
- dispersants
- thinners
- viscosifiers
- surfactants/detergents
- hydrate inhibitors (including MEG).

The concentration of process chemicals in discharged produced water is directly affected by the initial dosage concentration, solubility of the chemical in water and MEG and the level to which it decays or is neutralised during the production process. Initial dosage concentration range is specified by the chemical supplier and then fine-tuned by the operator to achieve optimum performance of the chemical in combination with the other chemicals and the hydrocarbons.

A review of ecotoxicity data (Hinwood et al. 1994) found MEG to be slightly toxic (1000–10 000 LC50 (mg/l)) to almost non-toxic (10 000–100 000 LC50 (mg/l)). The MEG is readily biodegradable in water with degradation likely to occur through aerobic bacterial activity. No acute or chronic impacts on marine organisms resulting from discharge of MEG are expected given its low toxicity and that all waste water streams will be biotreated then filtered.

Upon discharge contaminants in the treated waste water undergo a number of degradation or weathering processes, including:

- dilution
- evaporation of volatile components
- adsorption to particles and sedimentation
- biodegradation
- photodegradation.

Collectively, these processes tend to decrease the concentration of chemicals in the treated waste water plume and thereby decrease its toxicity to marine organisms. However, weathering is a complex process and difficult to predict with accuracy. It may produce new chemicals or result in speciation of chemicals in the mixture to forms that are more bioavailable and toxic than the original chemicals. Therefore, it is possible that waste water may not lose toxicity and could even increase in toxicity during the weathering process (Neff 2002). Furuholt (1996) suggests however, that these transformation processes are more likely to cancel each other out for mixtures with more than five toxicants.

For the Pluto LNG Development, dilution is likely to be the most effective process for reducing the inorganic and organic contaminants. Evaporation will also be important for removing volatile components.

Relevant Commonwealth and State Legislation and Guidelines: The fate and effects of waste water has been considered in respect to the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000 trigger values for toxicants at alternative levels of protection as well as the key performance indicators that CALM (2005) prescribed for marine parks and conservation areas. These are as follows:

- Sanctuary, special purpose (mangrove protection), special purpose (benthic protection), special purpose (intertidal reef protection) and recreation zones – no change from background levels, as a result of human activities.
- General use, special purpose (multiple use) and special purpose (pearling or aquaculture) zones of the marine park and conservation areas of the marine management area – no change from background levels, except in areas approved by the appropriate government regulatory authority. The area not meeting ANZECC and ARMCANZ guidelines (ANZECC/ARMCANZ 2000) is not to exceed 1% (by area) of these zones.
- Commercial (aquaculture) areas and unzoned areas of the marine management area – maintained in a natural state, except for areas where some level of acceptable change is approved by the appropriate government regulatory authority.

Consideration has also been given to the levels of ecological protection proposed within the 'Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives' (DoE 2006a) for areas within Mermaid Sound (**Section 1.6.1**).

Assessing the Risk from Pluto LNG Development Waste Water: Toxicity of treated waste water to marine organisms depends on the chemical compounds present and the exposure duration (acute or chronic). The toxicity of most hydrocarbons for example, depends on attainment of a critical volume or concentration in the tissues of aquatic organisms (Neff 2002). The toxicity of hydrocarbons in mixtures is additive, and the toxicity of a complex mixture such as Pluto LNG Development waste water therefore depends on the total concentration of bio-available hydrocarbons and degradation products in the water to which aquatic organisms are exposed.

The internationally accepted 'PEC:PNEC' approach was used to demonstrate the risk associated with the proposed Pluto LNG Development waste water discharge. The Predicted Environmental Concentration (PEC) was simulated using a dispersion model and is an estimate of the expected concentration of a chemical to which the environment will be exposed during and after discharge of that chemical. The Predicted No Effect Concentration (PNEC) is derived from ecotoxicity data and is the concentration below which it is believed there will be no detrimental effect to the environment. It relies on the assumption that a single value captures the concentration at which no toxic response (acute or chronic) is expected in the target population of marine biota. This concentration represents a toxicity value for the waste water prior to discharge to the ocean and takes into consideration all chemicals in the waste water and any synergy or antagonism between them.

The PNEC value for the Pluto LNG Development waste water was based on Whole Effluent Toxicity (WET) test results from Goodwyn Alpha produced water. Goodwyn Alpha, also a gas/condensate facility located on the North West Shelf, uses the same types and quantities of process chemicals that the Pluto LNG Development will most likely use; however, the extent of treatment will be far greater for Pluto LNG Development waste water. **Table 7-19** gives a summary of the major constituents for Goodwyn Alpha produced water.

The following ecotoxicological testing on Goodwyn Alpha produced water was undertaken by IRCE (2005):

- Microtox® – EC50, that is, the concentration of produced water that causes a 50% reduction light output from the marine bacteria *Vibrio fischeri*
- algal growth inhibition – IC50, that is, the concentration of produced water that causes a 50% reduction in growth
- rock oyster larval development – EC50, that is, the effective concentration of produced water causing abnormality in 50% of the test organisms

Table 7-19 Summary of the Major Chemical Class Concentrations contained within the Goodwyn Alpha Produced Water after Pump Out

Chemical Class	Concentration (mg/L)	% Distribution
Aliphatic Hydrocarbons	17	3.31%
Phenols	6.43	1.26%
Monocyclic Aromatic Hydrocarbons	2.66	0.52%
Naphthalenes	0.093	0.02%
Other PAHs	0.0	0%
Organic Acids	481	94.17%
Metals	3.71	0.73%
Total	510	100%

Source: IRCE 2005

- juvenile tiger prawn acute toxicity – LC50, that is, the concentration of produced water causing mortality to 50% of the test organisms
- sea urchin fertilisation – EC50
- sea urchin larval development – EC50.

The chronic algal growth inhibition endpoint was the most sensitive to the produced water with 96 hour LC50s of 9.6% and the lowest chronic No Effect Concentration (NOEC) for this test was 3.13%. Goodwyn Alpha produced water was therefore conservatively estimated to require 32 dilutions to have no observable effect on the marine environment (IRCE 2005). This value was assumed to be representative of the toxicity of the most sensitive organism in tropical waters to Goodwyn Alpha produced water. However, the IRCE (2005) study did not apply a safety factor to the NOEC in order to derive an estimated 'safe' dilution for the produced water in seawater (that is, it did not derive a PNEC). This is contrary to international practice which requires additional safety factors of 10–1000 to be applied to NOECs in order to derive a PNEC, depending on the amount and type of toxicity testing data available. The safety factor approach may be considered overly conservative however, as it takes into account only the most sensitive test species and the other toxicity data are discarded. A review of the limitations of safety factors by Chapman et al. (1998) suggests that safety factors for laboratory-to-field extrapolations should not exceed ten and may be much less. Based on these recommendations, a nominal conservative safety factor of 45 was applied to the Goodwyn Alpha dilution rate to derive a safe dilution rate for Pluto LNG Development untreated produced water of 1440 dilutions.

Based on the very high levels of treatment of produced water and the other co-mingled waste water streams, a conservative dilution factor for Pluto LNG Development treated waste water of 200 was applied. This dilution factor is based on a reduction in toxicity resulting from treatment of waste water to achieve a reduction in potentially toxic constituents including oil in water, biodegradable chemicals and process chemicals. A dilution factor of 200 (PNEC = 0.5%) will achieve a concentration of Pluto LNG Development treated waste water that will have no observable effect on the marine environment and will meet 99% species protection (that is, a high level of ecological protection according to DoE (2006a)). This PNEC will be confirmed by Whole Effluent Testing (WET) once a sample of Pluto LNG Development produced water is available.

Waste Water Fate and Trajectory Modelling: This section describes the likely fate and trajectory of discharged treated waste water into Mermaid Sound based on near field and far field modelling undertaken by Rob Phillips Associates (2006). Near field dilution was simulated using the Cornell Mixing Zone Expert System (CORMIX), a United States Environmental Protection Agency (USEPA) recommended analysis tool for point source discharges to receiving waters (Jirka et al. 1996). Far field dilution was predicted using a proprietary random walk particle tracking dispersion model. The models were driven by velocity fields generated by a detailed hydrodynamic model for the area and by wind profiles representing summer, winter and transitional seasons. Models were run for a period of three days; this was a conservative period given that the PNEC value (0.5%) was met within a few hours. Maximum predicted treated waste water discharge rates were applied to represent the worse case concentrations expected for the lifetime of the facility.

For the purposes of waste water modelling a six port diffuser was assumed in which the ports would discharge horizontally in alternating directions perpendicular to the outfall pipe. The diffuser parameters are provided in **Table 7-20** and an indicative diffuser design arrangement and location is presented in **Figure 7-5**. The diffuser design will be finalised during Front End Engineering and Design.

Table 7-20 Modelled Diffuser Design Parameters

Parameter	Value
Water depth	8.7 m Lowest Astronomic Tide (LAT)
Outfall Pipe	
Outfall pipe outside diameter	140 mm
Outfall pipe internal diameter	120 mm
Diffuser	
No of ports	6
Internal diameter of ports	39 mm
Discharge orientation	horizontal
Port spacing	4 m
Pipe: total port area ratio	65%
Depth	1 m above seabed
Effluent discharge	0.012 m^3/s (6000 bbl/day)
Port discharge velocity	1.57 m/s
Port froude No.	24

Initial dilution analysis predicts that the waste water plume will rise to the surface under the influence of its own buoyancy, where it will spread across the sea surface and then be transported by the ambient currents. Strong currents in the area along with the action of the diffuser typically reduce concentrations of waste water to below the PNEC of 0.5% within a short distance. For example, at ambient current speeds of 0.05 m/s or greater (likely to occur approximately 70% of the time), during mid tide, initial dilution rates of more than 1:900 are achieved within 2–3 m of point of discharge (**Figure 7-4**).

Periods of low water depths and weak ambient current speeds are the worst case conditions for mixing. Near field modelling during slack water with current speeds of 0.02 m/s predicts dilutions of 1:100 (1% waste water) within 10 m of discharge and 1:300 (0.33% waste water) within 50 m of discharge. Far field modelling however, which takes into account recirculation and build up over the point of discharge during low current speeds, predicts dilution of 1:250 (0.4% waste water) within 50 m of discharge. These worse case conditions are only prevalent during neap tides and may occur for less than 10% of the time over a fourteen day neap-spring tidal cycle (Rob Phillips Associates 2006).

Mixing Zone: Based on the results of the fate and trajectory modelling for worst case conditions, a mixing zone has been set at 50 m. **Figure 7-5** shows the location of the proposed mixing zone. Given a mixing zone of 50 m from each side of the diffuser, a 10 000 m^2 (1 hectare) mixing zone area is proposed. At the edge of this mixing zone the PNEC of 0.5% (200 dilutions) is predicted to be met at all times, under all conditions. Outside of this mixing zone a high level of ecological protection (DoE 2006a) will be met at all times and the ANZECC 99% species protection level will be met for metals and organic constituents likely to be in the discharged treated waste water. Within the mixing zone a low level of ecological protection is assumed to apply.

The concentration of contaminants likely to be in untreated Pluto LNG Development waste water, derived from the Goodwyn Alpha analogue, have been compared to the threshold concentration of contaminants to meet 99% species protection level, as listed in the ANZECC and ARMCANZ (2000) water quality guidelines. The contaminant requiring the highest level of dilution (that is, the rate limiting factor) is zinc, which at a predicted initial concentration of 0.91 mg/l, requires 143 dilutions to meet ANZEEC and ARMCANZ (2000) water quality threshold for 99% species protection level. This is equivalent to a PNEC value of 0.7% concentration for zinc which will be met well within the proposed 50 m mixing zone given a PNEC of 0.5% will be met at the edge of the mixing zone.

The PNEC and mixing zone have been set conservatively, assuming a worse case scenario for the following reasons:

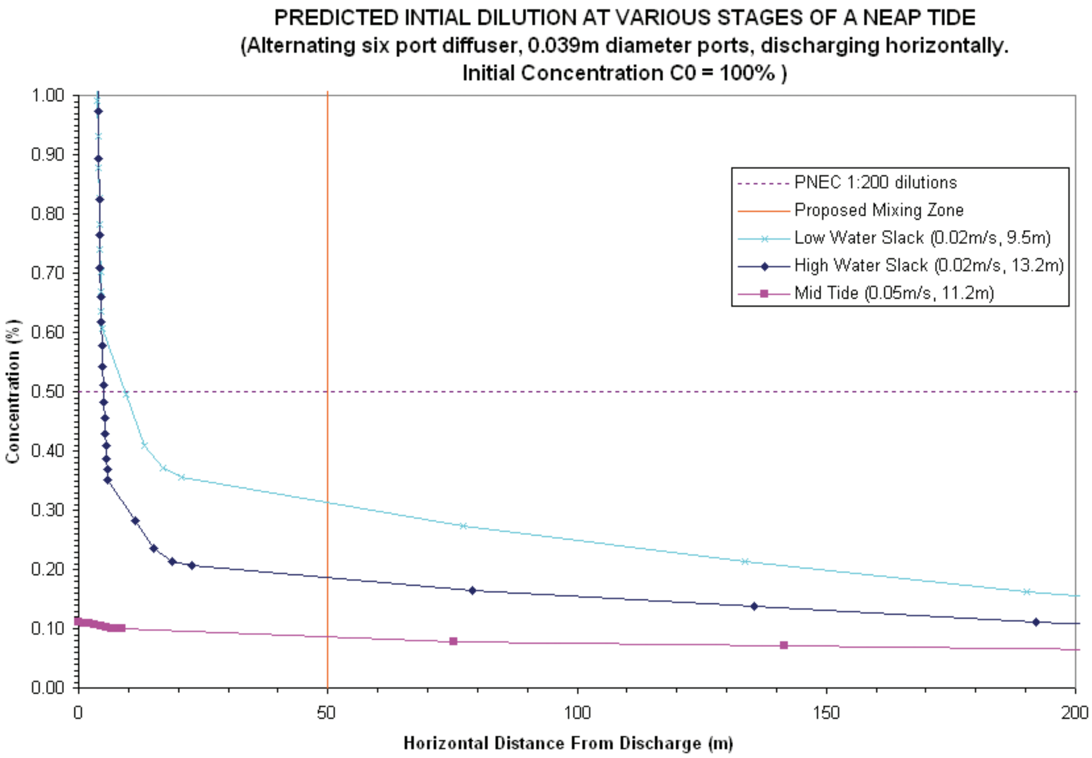
- Approximately 70% of the time the PNEC is likely to be met within a much smaller mixing zone (likely to be within 10 m).
- The dilution factor and PNEC concentration (0.5%) assumes a single stream discharge. In reality, the treated produced water discharge stream will be co-mingled with other discharge streams (treated sewage, grey water and AOC water) which will substantially dilute the concentration of contaminants contained within the produced water component.
- The modelling has been based on a maximum flow rate which is unlikely to be maintained for extended periods of time. A total waste water discharge rate of 960 m^3/day (6000 bbl/day) which comprises: 160 m^3/day (1000 bbl/day) formation water; 640 m^3/day (4000 bbl/day) condensed water; and 160 m^3/day (1000 bbl/day) of other freshwater based effluents such as treated sewage and grey water is considered a worse case scenario.
- Once oxidised, metal ions (including zinc) contained in the produced water stream are likely to precipitate out of the discharge stream into sediment. The modelling assumes that the residual metal ions contained in the produced water discharge stream have not been oxidised.

Potential Waste Water Impacts from Nearshore Discharge: Habitats potentially at risk from the discharge are the water column, shallow subtidal coral communities, mudflats, mangroves and rocky shore along the mainland and islands to the west. However, neither acute nor chronic environmental impacts are expected, mainly due to the level of treatment the waste water will receive prior to discharge, the level of dilution the plume will undergo and biodegradation, oxidation and sedimentation processes after discharge. There are no sensitive benthic habitats located within the 50 m radius mixing zone. The nearest sensitive habitat is coral reef located off Holden Point which is located approximately 400 m from the discharge point. There are no seagrass habitat or sea turtle and dugong aggregation and feeding areas located within the mixing zone.

Sedimentation of hydrocarbon compounds and heavy metal precipitates from produced water is not generally thought to be a problem in terms of impact on sediment quality as suspended particles are spread over a wide area meaning that concentration build up in the sediments is likely to be extremely low and probably of no significance (Furuholt 1996).

While evidence of bioaccumulation of some metals has been observed in recent years in oyster tissue at some sites within Mermaid Sound (URS 2005a), heavy metals (and other potential bioaccumulators) associated with Pluto waste water are likely to be very low and dilution in the receiving environment will

Figure 7-4 Comparison Between Near Field Dilution for Various Discharge Conditions



reduce them to background levels, well below chronic toxic thresholds within the mixing zone. For bioaccumulation to occur the rate of uptake from all sources must be greater than the rate of loss of the chemical from the tissues of the organism. Given the low concentrations of contaminants expected in Pluto LNG Development treated waste water and the intermittent exposure of marine organisms to the treated waste water plume, likelihood of bio-accumulation to toxic levels of contaminants are considered unlikely and bio-concentration is considered even less likely.

In summary, environmental impacts, from discharging treated waste water will be limited due to:

- the low rates of discharge
- the low contaminant concentration
- high rates of dilution at the points of discharge
- limited size of proposed mixing zone to achieve 99% species protection level
- limited potential for impact to sensitivities in the mixing zone (50 m) of the discharge location in Mermaid Sound
- longer term biodegradation and other weathering processes.

7.8.13.4 Preventative and Management Measures

The waste water streams generated from offshore vessels, the platform and drilling rig will be managed as described in **Section 7.8.13.2**. Suitable vessel waste water treatment plants will be maintained to ensure that risks to the marine environment associated with waste water are minimised.

All other waste water streams including produced water and waste water generated at Site B will be commingled, treated and discharged as one stream via a marine pipeline. Alternatives to marine disposal of this treated waste water are being considered and are discussed in **Section 3.6**. The residual total hydrocarbon in water concentration of waste water discharge will be less than 5 mg/l as an annual average for waste water discharged to Mermaid Sound.

A Waste Water Management Plan (**Table G-3**, **Appendix G**) will be prepared prior to operation. A comprehensive monitoring programme will also be implemented to confirm that there will be no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed trigger values for initiation of further studies and remedial actions as necessary.

The Pluto LNG Development waste water composition will be determined and Whole Effluent Toxicity (WET) testing undertaken as soon as first water becomes available.

7.8.13.5 Residual Risks

Ensuring that offshore contractors comply with international, national and state requirements and with Woodside's own policies regarding the discharge of waste water to the marine environment will result in a manageable ongoing low level risk.

The continuous discharge of waste water will result in minor contamination above background levels within Mermaid Sound. Any impacts on water quality will occur within a localised mixing zone with no nearby sensitive receptors; the predicted consequence is therefore moderate. The implementation of a Waste Water Management Plan will not reduce the likelihood of treated waste water discharge but it will ensure that impacts from treated waste water are kept to ALARP. Nevertheless due to the continuous nature of the discharge combined with the predicted moderate consequence the residual risk will be high. As treated waste water will be discharged regardless of whatever management measures are implemented the risk rating cannot be reduced below this level.

The consequence of the discharge to marine sediment quality is considered to be slight, and therefore the residual risk is low. Residual risks are shown in **Table 7-21**.

Figure 7-5 Proposed Mixing Zone and Diffuser Design for the Waste Water Discharge into Mermaid Sound

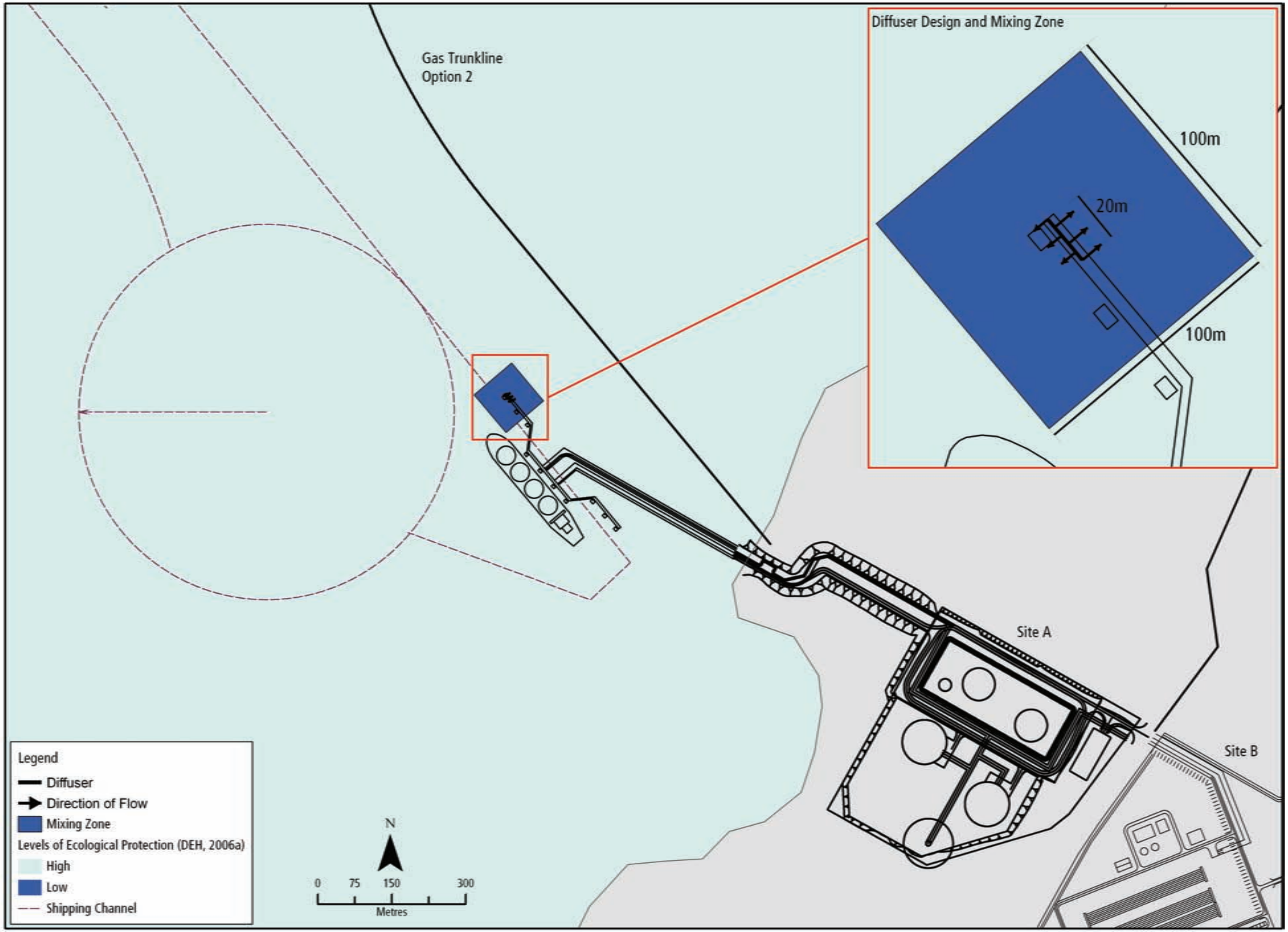


Table 7-21 Summary of Impacts, Management and Risks of Treated Waste Water Streams

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Sewage and grey water generated offshore	Sewage and grey water generated offshore, and by vessels involved with construction, drilling and ongoing operations	Sewage from vessels causes nutrient enrichment in coastal waters in Mermaid Sound Sewage and grey water generated on the offshore platform and on vessels causes nutrient enrichment in offshore waters	An IMO certified sewage treatment plant, capable of servicing the full complement of crew, will be in place on all construction, operation and decommissioning vessels. Sewage and grey water from contracted vessels will be disposed of in accordance with P(SL)A, MARPOL 73/78 and DPA requirements (within DPA limits). Vessels will not discharge untreated sewage or putrescible waste within 12 nm of land. Food wastes, sewage and grey water from drilling rigs and platforms will be, as a minimum, passed through a grinder or comminuter so that the final product will pass through a screen <25 mm diameter prior to disposal to the sea at a distance greater than 3 nm from land (as per P(SL)A requirements). Prior to discharge into port waters from an IMO approved sewage treatment plant onboard a vessel, the DPA will be provided recent laboratory results to confirm the sewage treatment plant is operating effectively.	E	2	L
Treated waste water discharged into Mermaid Sound via discharge pipeline	Generation and disposal of treated produced water, sewage, grey water, non routine contaminated water, AOC water and demineralised water	Formation of bacteria such as coliforms in untreated sewage Insufficiently treated waste water impacting on water quality of Mermaid Sound Waste water causing toxicity to some species	A Waste Water Management Plan (**Table G-3**, **Appendix G**) will be developed and implemented to manage treated waste water, and will include the following principles: • The residual total hydrocarbon in water concentration of waste water discharge will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound. • Pluto treated waste water composition will be determined and Whole Effluent Toxicity (WET) testing will be undertaken as soon as first water becomes available and periodically thereafter. Routine monitoring to ensure discharged waste water meets specified criteria. • The concentration of total hydrocarbon in treated waste water discharged to Mermaid Sound will be measured daily. • A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary. • A contingency plan will be developed to manage waste water in cases where unexpected volumes and/or quality of waste water are produced. • Routine monitoring to ensure treated waste water meets the Environment Quality Management Framework (EQMF) social use values at end of pipe or within a distance, from point of discharge, agreed with the relevant authorities. • Reporting procedures consistent with regulatory, local and Development requirements will be developed.	C	5	H
		Insufficiently treated waste water impacting on marine sediment quality		E	5	L
		Protected Areas		E	5	L

7.9 Dredging and Spoil Disposal

7.9.1 Introduction

Dredging is proposed for the Pluto LNG Development. Mermaid Sound has been subject to episodic large-scale dredging operations since 1965. Iron ore mining, salt production and offshore oil and gas exploration and production are the main drivers for industrial development in the area. During this period, both small and large-scale dredging programmes have been conducted as part of construction and maintenance of existing shipping channels, port facilities and subsea gas trunkline corridors. In excess of 31 Mm^3 of marine sediments have been dredged within Dampier Archipelago since 1965. The majority of this spoil has been relocated to the existing spoil grounds in Mermaid Sound, namely: spoil ground A/B (also known as northern and southern spoil ground) and adjacent to East Lewis Island. A historical summary of dredging activities within Damper Archipelago is provided in **Table 7-22**.

Table 7-22 Summary of Previous Dredging Activities within Mermaid Sound

Proponent	Year	Location of Dredging	Volume of Dredge Material (m^3)	Spoil ground
Hamersley Iron	1965	Capital dredging of shipping channel to Parker Point	2 500 000	Unknown
Hamersley Iron	1968	Deepening of shipping channel to Parker Point	1 500 000	Unknown
Hamersley Iron	1970–71	Widening of shipping channel and extension of the channel to East Intercourse Island Facility	760 000	Unknown
NWSV	Dec 1981–Sep 1982	North Rankin A Platform to Karratha Gas Plant	280 000	Various approved sites along route
Hamersley Iron	1981	Deepening and widening of shipping channel to Parker Point	400 000	Unknown
NWSV	1981	King Bay supply base	1 200 000	Onshore Area No 4
NWSV	Nov 1981–Dec 1982	Island Berth and Materials Offloading Facility	140 000	1 km north of MOF wharf
Hamersley Iron	1985	Maintenance dredging of East Intercourse Island berth and shipping channel	Volume unknown	Unknown
NWSV	Oct 1986–Jun 1987	LNG shipping channel	6 600 000	Spoil ground A/B
NWSV	Aug 1989–Sep 1989	Maintenance dredging of LNG shipping channel	149 700	Spoil ground A/B
Hamersley Iron	1989	Maintenance dredging of shipping channel	350 000	East Lewis Island spoil ground
Hamersley Iron	1991	Maintenance dredging of East Intercourse Island Berth	Volume unknown	Unknown
NWSV	1994	Berthing pocket for LNG ships	700 000	Spoil ground A/B
Hamersley Iron	1998	Capital dredging of shipping channel	2 000 000	East Lewis Island spoil ground
Hamersley Iron	1998	Maintenance dredging around berths	800 000	East Lewis Island spoil ground
Hamersley Iron	2000	Minor dredging around berths	5000	Onshore disposal
NWSV	2002	Trunkline System Expansion Project (TSEP)	2 600 000	Water depth > 30 m
DPA	Jan–Jun 2004	Dredging of shipping channel, swinging basin and berths	4 500 000	Spoil ground A/B
Hamersley Iron	Apr–Aug 2004	Capital dredging for Parker Point upgrade	3 100 000	East Lewis Island spoil ground, spoil ground A/B and onshore reclamation
Hamersley Iron	Oct–Nov 2004	Maintenance and Capital dredging for extension of Parker Point upgrade	500 000	Onshore reclamation
NWSV	May 2005–Jul 2006	LNG Phase V	3 300 000	Spoil ground A/B
		Total (estimate)	> 31 434 700	

The potential environmental impacts associated with dredging operations, although variable and site dependant are well documented and can be broadly characterised as follows:

- direct mortality and removal of benthic habitats by dredging vessels
- smothering of benthic habitats and species triggering stress, reduced rates of growth, reproduction and in the worst case, mortality
- alteration of seabed geomorphology either directly or indirectly (including particle size distribution) leading to longer term change in community structure
- alteration to the existing hydrodynamic regime
- near field and temporary increases in suspended sediments and turbidity levels from dredging and disposal operations which can:
  - result in adverse effects to marine biota by reducing light penetration through the water column thereby resulting in temporary reductions in productivity and growth rates
  - cause clogging and damage to the feeding and breathing apparatus of filter feeding organisms (Parr et al. 1998)
  - cause localised and temporary reduction in oxygen levels due to the release of potentially organic rich sediments into the water column
  - increase organic matter and nutrient availability to marine organisms subsequently resulting in eutrophic waters with knock-on effects for productivity of marine ecosystems
  - cause toxicological effects to marine organisms associated with the potential re-suspension of previously contaminated sediments as part of either the dredging or disposal operation.

Within Mermaid Sound there are a range of marine habitats and species that are sensitive to disturbance from dredging operations. The most sensitive are benthic primary producers: sessile marine organisms that live in or on the sediment. Primary producers include marine plants and invertebrate animals, such as scleractinian corals that acquire a proportion of their energy growth and survival from the photosynthetic algae that live in the coral. Benthic primary producers are important to the marine environment for their primary productivity, their provision of shelter for other organisms and their stabilising effects on the seabed and shoreline.

To avoid unacceptable losses of benthic primary producers in Western Australian waters, the EPA has issued Guidance Statement No. 29 which is a set of guidelines for the protection of marine benthic primary producers and their habitats (EPA 2004a).

The Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives was released in June 2006 (DoE 2006a). It presents the EPA's interim set of environmental goals (Environmental Values and Environmental Quality Objectives) which are spatially allocated (Levels of Ecological Protection) for state waters of the Pilbara Coast and extends beyond water quality to include sediment quality. Assessment of potential impacts has included consideration of this interim document.

In addition to the EPA guidelines, the Commonwealth DEH administers the National Ocean Disposal Guidelines for Dredged Material (Environment Australia 2002). Under the guidelines, specific levels of contamination are permitted, above which spoil is considered to be no longer suitable for ocean disposal.

Section 7.9.2 to **Section 7.9.6** describes the proposed Pluto LNG Development dredging programme, the alternative dredge spoil disposal options and dredging techniques that have been considered. The results of sediment plume dispersion modelling are presented to provide an indication of Total Suspended Sediment (TSS) and sedimentation patterns associated with the proposed dredging and dredge spoil disposal activities (**Section 7.9.7.7** to **Section 7.9.7.10**). A description of potential environmental impacts to marine biota and specifically to benthic primary producers located within Dampier Archipelago is provided in **Section 7.9.8** and **Section 7.9.9**, respectively. The proposed mitigation and management measures, together with monitoring measures are presented in **Section 7.9.15**.

7.9.2 Synthesis of Proposed Dredging Programme

The dredging programme will include dredging both within and outside of the DPA limits and will span approximately 24 months. A total of approximately 11 to 14 Mm^3 of dredge spoil is estimated to be generated from within the DPA limits from dredging activities associated with the Pluto LNG Development. Dredging associated with trunkline installation beyond DPA limits is estimated to generate approximately 1.5 Mm^3 of dredge spoil. This spoil will require subsequent disposal at dedicated spoil disposal grounds, in accordance with the Commonwealth Sea Dumping Permit process. A summary description of the proposed dredging programme for the Pluto LNG Development is provided in **Section 4**. The dredging programme will cover the following key activities (**Figure 4-12**):

1) construction of a navigation channel (approximately 10 km in length and 250 m in width), turning basin and berth pocket up to 13.5 m in depth to accommodate LNG and condensate tankers sized up to 210 000 m^3 and 115 000 m^3, respectively
2) installation of a subsea gas trunkline with landfall at the NWSV Karratha Gas Plant (that is, gas trunkline Option 1) or at Holden Point (that is, gas trunkline Option 2)
3) disposal of spoil from the turning basin and berth pocket into the existing spoil ground A/B and a northerly extension of this ground in Mermaid Sound

4) disposal of spoil from the navigation channel to a new deep water spoil ground (spoil ground 2B) located in water depth of approximately 30 m close to the entrance of Mermaid Sound

5) disposal of spoil from the nearshore sections of the gas trunkline to the existing Mermaid Sound spoil ground A/B and a northerly extension of this area or into a new spoil ground (5A) located beyond DPA limits

6) disposal of spoil from the offshore sections of the gas trunkline into spoil ground 5A.

7.9.2.1 Sediment Composition along the Navigation Channel

As discussed in **Section 6.2.4**, sediment samples were collected during a survey undertaken in January 2006 at various locations along the proposed navigation channel and gas trunkline route as part of the Commonwealth Sea Dumping Permit process for the Pluto LNG Development. The majority of samples analysed (108 in total) exhibited TBT levels below detection level (0.5 µg Sn/kg). Only two samples from two nearby sampling locations showed elevated TBT levels above detection level at 3.85 µg Sn/kg and 20 µg Sn/kg, respectively (normalised to 1% Total Organic Carbon). Both samples were obtained from the upper 50 cm of seabed. Samples taken from the same sites at depth (50–100 cm) indicate that the elevated TBT levels were restricted to surface sediments only. The sediments analysed from the survey are therefore considered to be clean and suitable for ocean disposal. A later survey focussed on screening the deeper sediments for polyaromatic hydrocarbons and metals below 1 m found sporadic levels of metals slightly above screening level as stipulated by the National Ocean Disposal Guidelines for Dredged Material (NODGDM). However, the 95% Upper Confidence Limit for all hydrocarbons and metals were below screening level. This is discussed further in **Section 6.2.4**.

Sediments sampled along the proposed navigation channel were found to vary widely in particle size distribution from location to location (**Figure 7-6**). Arrangements of the samples with respect to distance from Holden Point, indicates that there is a general spatial trend in size distribution. Samples collected at the south-west end of the survey area (that is, near Holden Point) and at the north-west end (towards West Lewis Island) have the highest proportion of silts and clays.

7.9.3 Dredging Programme Development Considerations

Dredging activities within the DPA limits will be undertaken over a 24-month period approximately and will require a number of different dredge vessels, techniques and procedures. A description of the proposed dredging activities and preliminary dredging schedule is provided in **Figure 4-12**. It should be noted that the schedule has dredging commencing in or around September 2007, subject to obtaining all necessary environmental approvals and confirmation of contractor availability.

The proposed dredging programme has been designed to ensure dredging will be consistent with the environmental principles to avoid, minimise, recycle and dispose. **Figure 7-7** provides a summary of the process that has been adopted to develop the proposed dredging programme which has taken into consideration relevant international, Commonwealth and state guidelines and legislation. The dredging programme has been developed in consultation with relevant stakeholders, particularly in determining appropriate spoil ground locations. Ongoing consultation is being undertaken with the DPA and existing port user groups.

Figure 7-6 Sediment Composition along the Navigation Channel (at 1 m depth)

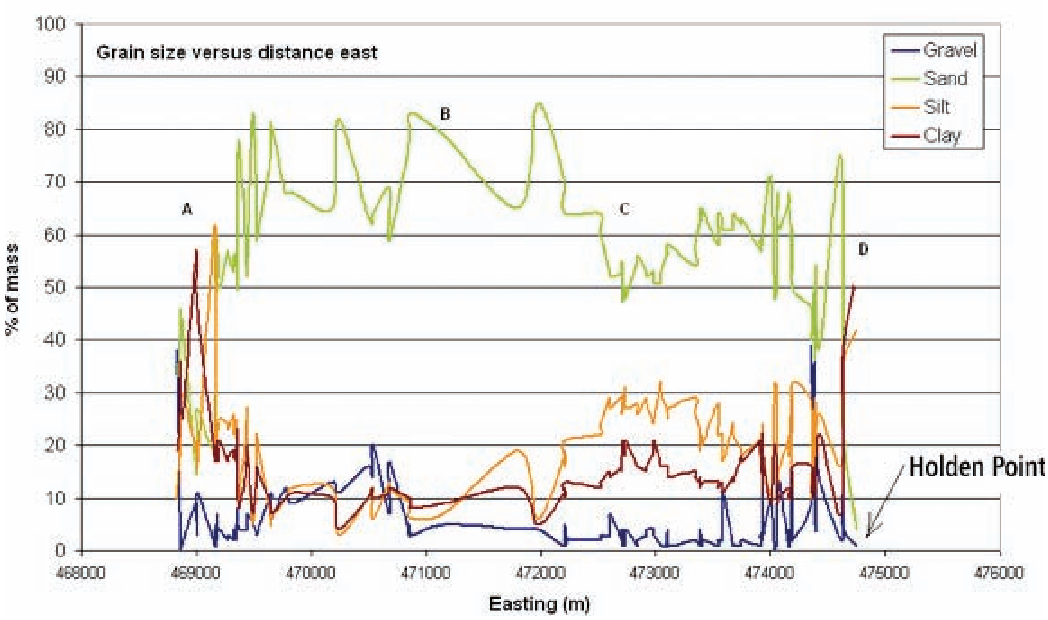
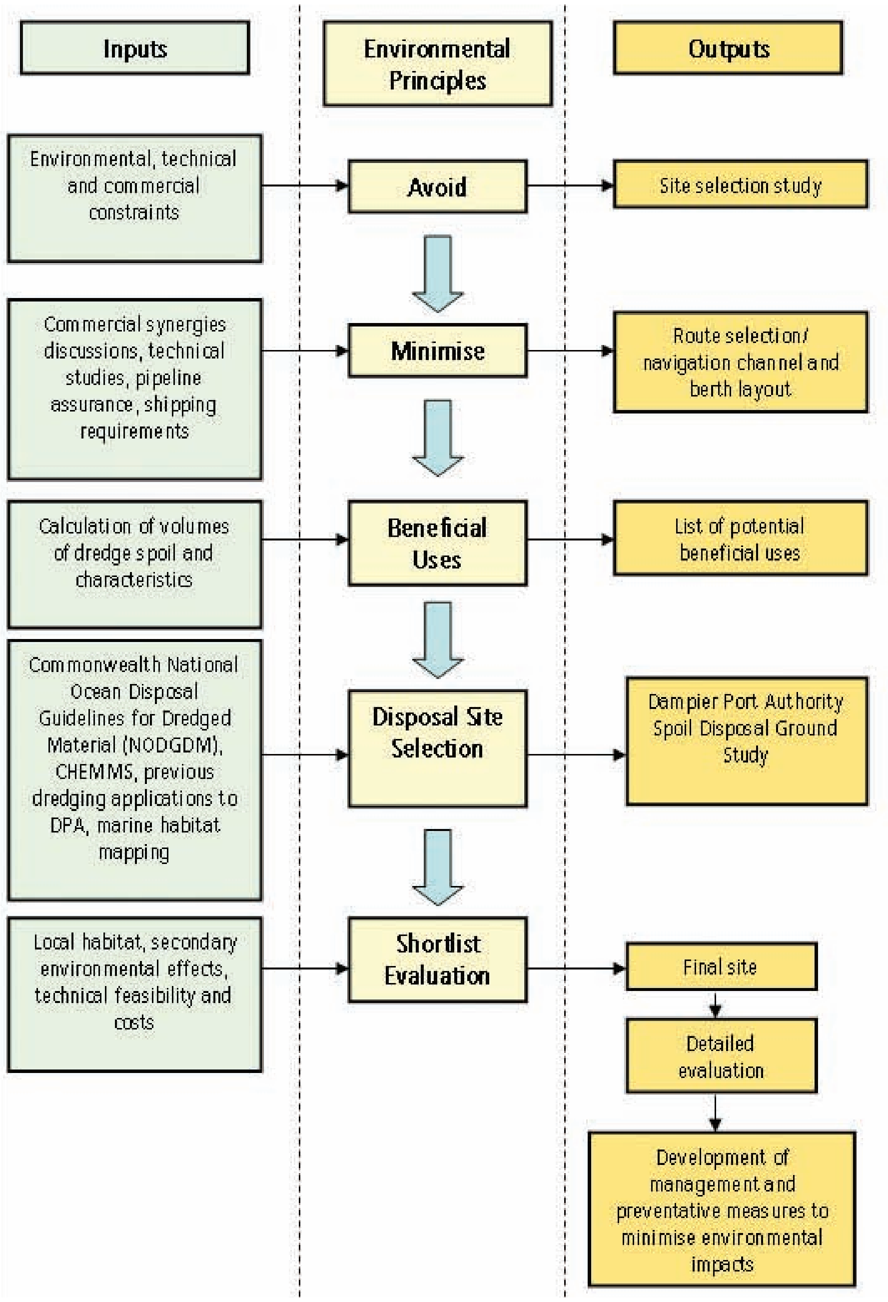


Figure 7-7 Dredging Programme Development Considerations



The development of the proposed dredging programme has included the following considerations:

Consideration 1 – Determining the Requirements for Dredging: A series of technical and commercial evaluations conducted early in the design stage have determined a fundamental requirement for the construction of a navigation channel to allow LNG and condensate tankers to transport product to overseas markets. The size of export tankers required to make the Pluto LNG Development economically feasible necessitates access to deep water (13.5 m water depth) port facilities.

Consideration 2 – Investigating Opportunities to Minimise Impacts: Woodside has considered alternative site options including an option to move the NWSV to an 'open infrastructure' model which would see new LNG trains owned by other resource owners built on the NWSV land and utilising existing infrastructure. Woodside proposed this option to the joint venture partners in the NWSV but it was rejected. Therefore, this alternative is not feasible as NWSV infrastructure and land is not available for the Pluto LNG Development.

A variant of the above option was to minimise the need for dredging by aligning the Pluto LNG Development navigation channel so that it joins the existing NWSV channel. Joining the channels before they deviate and bend to the north (**Figure 4-10**) was discounted because, firstly, this does not result in any significant reduction in dredge spoil (a channel from the proposed Pluto LNG Development jetty to the NWSV channel would cross an extended section of shallow water requiring a greater amount of dredging which would offset any reductions achieved by shortening the overall channel length). Secondly, the NWSV channel would need to be widened and deepened to accommodate the Pluto LNG Development export tankers, which, aside from logistical difficulties associated with dredging in an existing channel, would negate the benefits to be achieved. Joining of the channels after the 'bend' remains subject to ongoing studies, the critical issues that remain to be resolved relate to the amount and location of hard granophyre bedrock.

The opportunity to use the existing DPA facilities was dismissed due to shipping hazards, schedule constraints and technical feasibility. In particular the hazards of having LNG tankers sharing a narrow channel with a large number of other ships, including liquid ammonia tankers, weighed heavily in the decision-making process as did the requirement for widening and deepening the channel to accommodate the Pluto LNG Development tankers.

Once it was determined that dredging could not be avoided, the next step in the process was to identify opportunities to minimise environmental impacts through an assessment of potential beneficial uses.

Consideration 3 – Identifying Beneficial Uses of Dredge Spoil: The potential re-use of dredge spoil from the Pluto LNG Development has been considered in parallel to a DPA study to identify potential spoil ground options. The re-use of dredged spoil (either onshore or offshore) is dependent upon a number of factors including:

- the volume of dredge spoil generated – certain re-uses may only require small volumes of material, leaving a large residual volume requiring disposal
- the physical characteristics of the spoil – sediments that are too fine are likely to have limited re-use potential
- potential for contaminated spoil will limit the opportunities available for re-use and also prove costly to clean
- the demands for dredge spoil from third parties – limited demand will reduce the opportunities for re-use.

The onshore re-use or reclamation of dredged spoil has been investigated and the main potential beneficial use is to provide fill material for land fill projects on the Burrup Peninsula. An area of potential land development between the Hamersley Iron and Dampier Salt causeways has been put forward by stakeholders; this would have the benefit of creating land for future use (Location 2, **Figure 7-8**). The onshore reclamation of dredge spoil at this location or elsewhere on the Burrup Peninsula is not considered viable for the following reasons:

- A demand for dredge spoil would need to coincide with the dredging operations planned for 2007/2009.
- Available space for onshore storage and settling of fines from tail waters is limited.
- Significant environmental impacts to extensive areas of intertidal and subtidal habitats would result from reclamation activities.
- Only engineering grade material would be suitable for reclamation and a large proportion of dredge spoil from the Pluto LNG Development will be comprised of silty/ fines material which is not considered suitable for this use.
- Onshore reclamation would require third party approvals which could potentially compromise the Pluto LNG Development schedule.

Beach replenishment was eliminated from consideration due to the absence of beaches requiring replenishment in the region and incompatibility of the spoil characteristics. An opportunity to re-use a portion of the dredge material from trenching of the gas trunkline as backfill material is a feasible option. This will reduce the volume of spoil that will require disposal.

Consideration 4 – The Most Appropriate Site to Dispose of Dredged Spoil: The selection of a suitable spoil disposal ground has taken into consideration various criteria, including the capacity of existing spoil grounds, the predicted direct and indirect environmental impacts associated with each option, social impacts, schedule and cost implications. Selection of spoil disposal sites is discussed further in **Section 7.9.4**.

7.9.4 Selection of Spoil Disposal Sites

Selection Criteria

Key considerations for selection of dredge spoil disposal sites were based on the principles of ecologically sustainable development and included:

- Geographic Location of Dredging Activities: The location of the proposed gas processing plant directly influences the location of the export facilities, which in turn directly influences the area where dredging will occur and the location of the dredge spoil disposal site(s).
- Physical Suitability of the Disposal Site(s): The spoil site(s) need to have suitable depth and should not be susceptible to high levels of re-suspension.
- Minimisation of Environmental Impacts: Environmental impacts associated with dredge spoil disposal include direct physical impacts on benthic communities and secondary impacts associated with the temporary increase in suspended solids and sedimentation adjacent or near to the disposal site. In broad terms, the preference is for disposal at existing spoil grounds or disturbed areas followed by areas with approximately similar sediment/spoil characteristics and relatively lesser environmental significance.
- Development Schedule and Economic Feasibility: The radius within which the spoil ground(s) is to be located is constrained by the logistics of vessel movements affecting both schedule and costs. A longer or extended dredging programme will increase fuel usage and result in increased greenhouse gas, NOx and oxides of sulfur emissions from vessel exhausts. A six hour maximum turnaround time for disposal of spoil by barge was set, which equated to approximately 30 km radius from the dredge activity. Therefore, only locations within approximately 30 km of dredging activity were considered for potential spoil disposal.

Site Screening Process

At the same time that Woodside was evaluating potential spoil disposal sites, the DPA had separately commissioned a study to identify potential spoil ground options. The draft outcomes of the DPA study, which were made available to Woodside, identified seven potential offshore disposal grounds for evaluation, all of which were included in the Woodside study.

The area studied for potential spoil disposal sites can, for the purposes of the DPA study, be separated into three zones (**Figure 7-8**):

- inner Dampier Port that encompasses the existing East Lewis spoil ground 3a as well as a site considered as part of the DPA study, namely 'Site 5'
- middle Dampier Port that encompasses the existing spoil ground A/B (also referred to as the Northern and Southern spoil grounds and labelled as '3b' in **Figure 7-8**)
- outer Dampier Archipelago in waters greater than 30 m depth including:
  - a site considered as part of the DPA study, namely 'DPA Site 1'
  - two deep water sites proposed by Woodside ('Site 2A' and 'Site 2B') for disposal of spoil from the navigation channel, berth pocket and turning basin dredging programme
  - a deep water site proposed by Woodside ('Site 5A') for disposal of spoil from side cast material during installation of the gas trunkline.

The inner areas represent an advantage of least distance from dredge location and hence least time and cost for disposal. The disadvantages are limited capacity for additional spoil disposal at the existing East Lewis spoil ground (3a); the shallow approach to East Lewis spoil ground (which would effectively preclude operation of larger barges), potential carryover or re-mobilisation of spoil into adjacent navigation channels in the case of DPA Site 5, and potential conflict with other users. East Lewis spoil ground 3a has limited capacity, estimated at 0.5 Mm^3, and is relatively shallow. Due to the draft of vessels being operated, the East Lewis spoil ground 3a would not be suitable for the disposal of spoil from the turning basin/berthing pocket area. This site was not carried forward for further consideration.

Middle areas represent an advantage of relatively less distance to the spoil ground and, in the case of spoil ground A/B, a previously used site (**Figure 4-15**). The area to the north of the northern portion of spoil ground A/B has a low density benthic community and has been subject to previous low levels of disturbance from anchoring activities. It is constrained by the intention of DPA to retain areas for protected anchorage with at least 15 m depth and by strong currents through the passage between Gidley and Angel Islands that could re-suspend and remobilise spoil.

The following two sites from the middle area were carried forward, these being:

- the existing spoil ground A/B (including two subset areas, namely area CDG and area CDEFIH)
- Site 4 which comprises a small extension to the north of spoil ground A/B (area ABCD).

In recognition of the constraints described above, the extension area ABCD to the north of spoil ground A/B would be limited to approximately 300 m width to the north.

Outer areas, beyond 30 m water depth, represent an advantage of relatively unconstrained volume and type of spoil. Disadvantages relate to the relative lack of knowledge of seabed communities in the areas and the additional travel time between dredge site and spoil disposal site (and hence increase in time and costs, fuel consumption and exhaust emissions).

The short-list of spoil disposal sites carried forward is illustrated by **Figure 7-8** and comprises:

- Middle Area: Spoil ground A/B (area 3B), northern extension to A/B (Site 4)
- Outer Area: Four sites namely Site 2A, Site 2B and offshore gas trunkline disposal Site 5A.

Spoil Ground A/B: The capacity of the existing spoil ground has been calculated to be in the order of 2 to 4 Mm^3 of bulked spoil after completion of the NWSV Karratha Gas Plant LNG Train 5 expansion and Pilbara Iron's proposed dredging activities. DPA Marine Notice April 2006 restricts where spoil material may be placed in the existing spoil ground A/B based on nature of the spoil material. Looser spoil materials (referred to by DPA as Category 3 material) may only be disposed to the inner areas of the northern portion of the spoil ground. Coarser material can be disposed on the western and northern margins of the combined area and eastern margin of the southern portion of the spoil ground.

Northern Extension to Spoil Ground A/B: Restricting the extension of spoil ground A/B to a strip approximately 300 m wide extending across the northern margin of the existing spoil ground A/B avoids the potential for significant re-suspension of material and limits the potential for interference to 15 m depth anchorage areas (**Figure 4-15**). The extension area provides a theoretical in-situ capacity of approximately 1.8 Mm^3. The area would not be suitable for disposal for fine sediments due to the potential for re-suspension; however, disposal of coarser material would be consistent with intent of the restrictions stated within the DPA Marine Notice.

Outer Areas: Modelling was carried out to predict potential impact of spoil disposal at two sites to the north of Dampier Archipelago (Sites 2A and 2B on **Figure 7-8**) to aid in comparative evaluation of the sites. Results of the modelling indicated that spoil disposal into Site 2A would disperse more widely than into Site 2B due to stronger tide and current effects at this location. Modelling predicted that spoil disposal into Site 2A would result in elevated TSS concentrations on the subtidal reefs at Legendre Island. High occurrences of dugongs and turtles have been observed on the seaward side of Hamersley Shoal at the entrance to Mermaid Sound, close to Site 2A (J Stoddart [MScience] 2006 pers comm. 10 May, 2006). Subsequently, the selection of Site 2A as a spoil disposal site would have relatively higher potential for significant disturbance to dugongs and sea turtles. Site 2B was considered to be preferable on the basis that it would result in less mobilisation of spoil from the spoil ground and potential reduced impacts to sea turtle, dugong and benthic habitats. Site 2A was not considered further.

Spoil disposal from trenching of the gas trunkline beyond DPA limits will be side-cast into spoil grounds located 1–2 km away from the trunkline trench at spoil ground 5A.

Sites Selected

Table 7-23 presents the proposed dredge spoil disposal plan concluded from the detailed site selection.

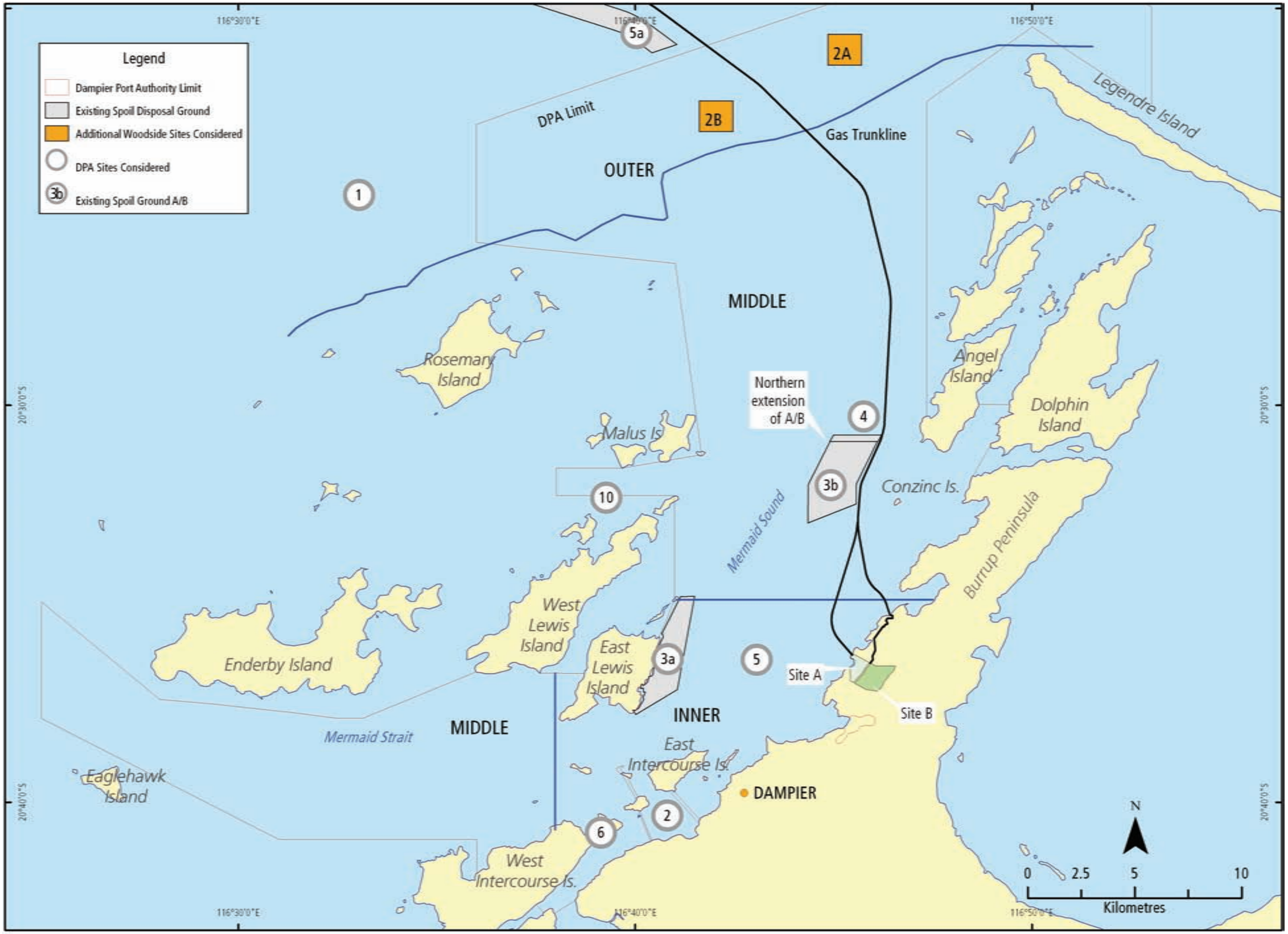
Dredge spoil from construction of the gas trunkline in deeper waters (20–50 m) will be disposed of adjacent to the trunkline easement at a distance of 1–2 km.

Table 7-23 Proposed Dredge Spoil Disposal Plan

Spoil Source	Spoil Type	Spoil Ground A/B –Northern (Area CDG)	Spoil Ground A/B- West and Northern Margins (Area CDHIEF)	Northern Extension of Spoil Ground A/B (Area ABCD)	Deep water Spoil Ground 2B	Trunkline Backfill and Cover	Deep Water Spoil Ground 5A
Turning basin and berth pocket	Sediment	✓					
	Coarse material		✓	✓	✓	*	
Navigation channel	Sediment				✓		
	Coarse material				✓	*	
Gas trunkline Option 1 and 2 within DPA limits	Sediment	✓			✓		
	Coarse material				✓	*	
Gas trunkline beyond DPA limits	All						✓
Approximate volume within DPA limits (Mm^3)		2.0–3.0		1.5	8.0–10.0	1.0	

** subject to further analysis of likely spoil volumes and characteristics*

Figure 7-8 Spoil Disposal Grounds Initially Considered



7.9.5 Description of Existing Environment at Spoil Grounds

The proposed spoil disposal grounds are located both within and beyond the Dampier Archipelago. As part of a baseline nearshore marine survey conducted by SKM, the benthic habitat at two of the existing and proposed spoil grounds (spoil ground A/B- northern extension and deep water spoil ground 2B) was investigated using an underwater towed video camera which enabled real-time, geo-referenced habitat classification of the seabed according to substrata, benthos and individual organisms. Four transects were conducted across the northern end of the existing Mermaid Sound spoil ground A/B and the proposed northern extension of this ground. The survey also included the deep water spoil ground 2B but did not include deep water spoil ground 5A, which had not been determined at the time of survey.

7.9.5.1 Spoil Ground A/B and Northern Extension

The substrate inside the spoil ground consists of soft sand sediment habitat which is widespread within Mermaid Sound and confirms the CALM habitat mapping for the area (**Figure 6-12**). During the nearshore survey a few individual fan corals, sea whips, sea pens and macroalgae were observed in isolated areas.

The key environmental sensitivities in the vicinity of spoil ground A/B and northern extension are presented in **Table 7-24**. Spoil ground A/B is located within a humpback whale female and calf resting area within Mermaid Sound (**Section 6.3.6**). This area is utilised by humpback whales in spring, during their southerly migration to colder, Antarctic waters. The spoil ground does not interfere with dugong habitat or sea turtle nesting areas. The nearest dugong habitat and sea turtle nesting areas to spoil ground A/B are located approximately 4 km and 12 km away, respectively. Subtidal coral reef is located approximately 1.6 km to east of the spoil ground near to Angel Island.

7.9.5.2 Deep Water Spoil Ground 2B

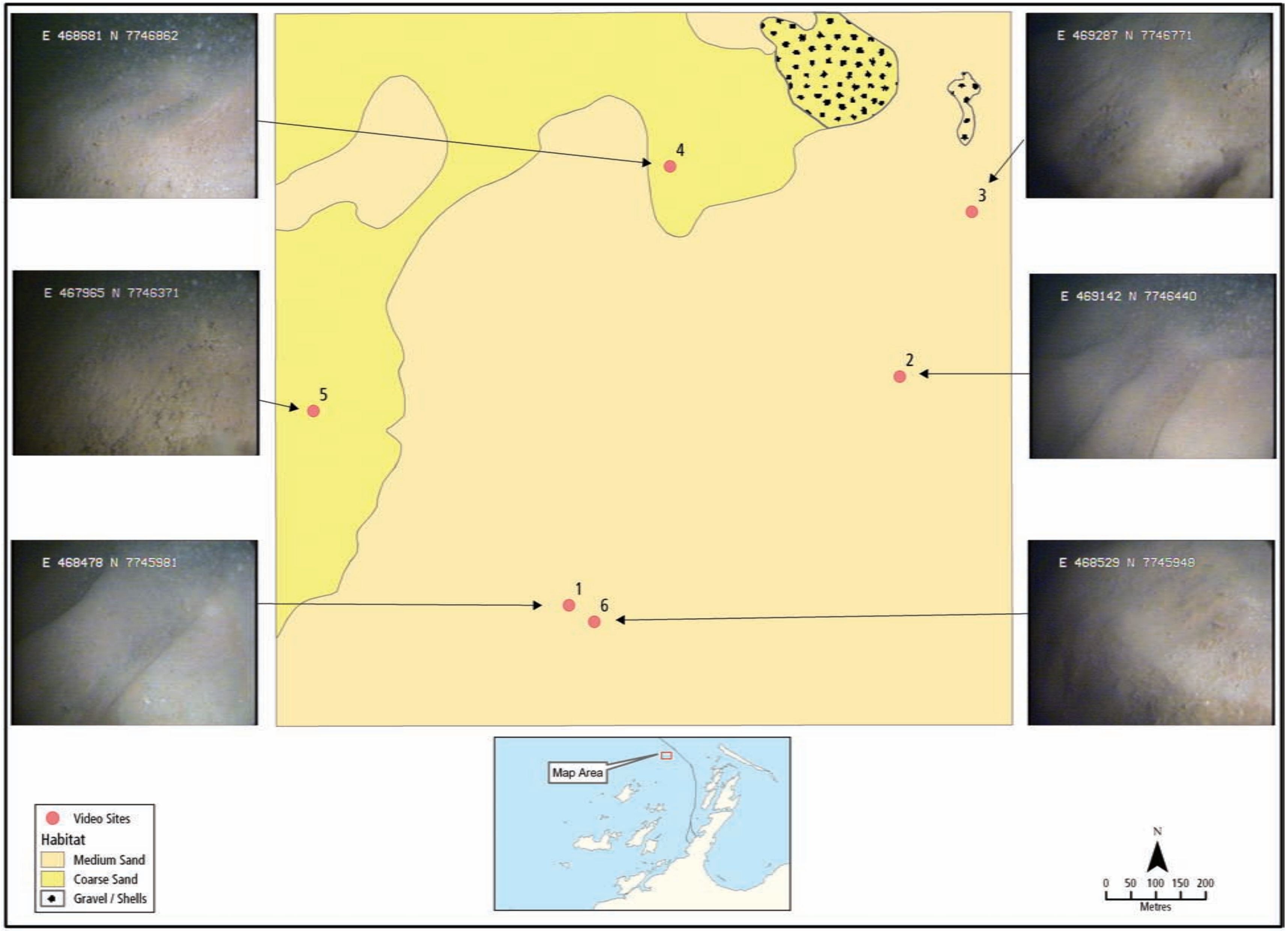
Multibeam scanning of the proposed spoil ground revealed a slightly sloping seabed dropping gently from approximately 31 to 34 m in a northerly direction (Fugro 2006). Further side-scanning indicated a uniform seabed comprised of sandy and silty sediments throughout the proposed spoil ground area with a small patch of coarser material found in the north-east corner (**Figure 7-9**). Sediment grab samples on six random sites confirmed the sediments to be fairly uniform and comprised predominantly of sand, with particle size class 0.06–2 mm ('sand') dominating all samples (>60%). Video footage at the same six sites confirmed the sediments to be comprised of sand with no visible epibiota (**Figure 7-9**). The baseline nearshore marine survey, conducted by SKM in 2006 as described in **Section 6**, included two video transects on the proposed spoil ground 2B, each approximately 1 km in length. The seabed was confirmed to consist of soft sand with epibiota such as seapens, macroalgae and seawhips was observed in isolated areas, albeit in very limited quantities.

Sediment samples from each of the six video sites shown in **Figure 7-9** were analysed for metals, namely antimony, arsenic, cadmium, chromium, copper, lead, nickel, silver, zinc and mercury. Analysis consistently returned levels of these metals below screening levels as set in the NODGDM (EA 2002). The only exception was one replica from Site 6, which returned nickel (35 mg/kg) slightly above screening level (21 mg/kg). The other two replicas from this site were both well below screening level (8 and 10 mg/kg, respectively).

Samples for infauna were also obtained on each of the six sample sites. Results will be made available when analysis is complete.

The proximity of sensitive receptors to the spoil grounds locations is presented in **Table 7-24** and **Figure 7-10**. Humpback whales migrate through the general area past the Burrup Peninsula on their southerly migration (**Figure 7-10**). The spoil ground is located approximately 8 km away from known dugong habitat / feeding areas and 7 km away from sea turtle aggregation areas. The nearest subtidal coral reef to the spoil ground is located 6.5 km to the south. The proposed spoil ground is located in a prohibited anchoring area.

Figure 7-9 Sidescan and Still Footage of Proposed Spoil Ground 2B



7.9.5.3 Deep Water Spoil Ground 5A

The seabed habitat at spoil ground 5A was not sampled as part of the marine baseline environmental survey. However, seabed samples were collected as part of a preliminary geotechnical survey along the gas trunkline by EGS Limited and interpreted by Golder Associates (2006). The data from this survey have been interpreted to provide an indication of the expected seabed conditions adjacent to the trunkline route at spoil ground 5A (**Figure 4-15**). Both grab samples and core samples were recovered at intervals along the trunkline route. The grab samples were limited to the top 20 cm of seabed.

Areas of seabed along the trunkline route that are located adjacent to spoil ground 5A can be categorised into two general zones (Golder 2006) in relation to sediments encountered during the survey, namely:

- **Zone 1a**: Sand, fine to medium grained with up to approximately 30% shell fragments up to 60 mm size, trace of silt and soft coral with size up to approximately 95 mm size. Silt and sandy silt.
- **Zone 2a**: Sand, gravely sand, silty sand and cemented sand: fine to coarse grained sand, well graded, with up to approximately 20% shells and shell fragments (up to 35 mm size), with some silt, occasional sandy gravel. Some cemented sand calcarenite particles.

The majority of sediment samples collected along the gas trunkline and adjacent to spoil ground 5A were comprised of fine to medium and fine to coarse sands with shell fragments. Only a few samples recorded presence of calcarenite and coral. Based on the results of the survey it is anticipated that the seabed habitat at spoil ground 5A will be comprised of sediments similar to those encountered along the gas trunkline route.

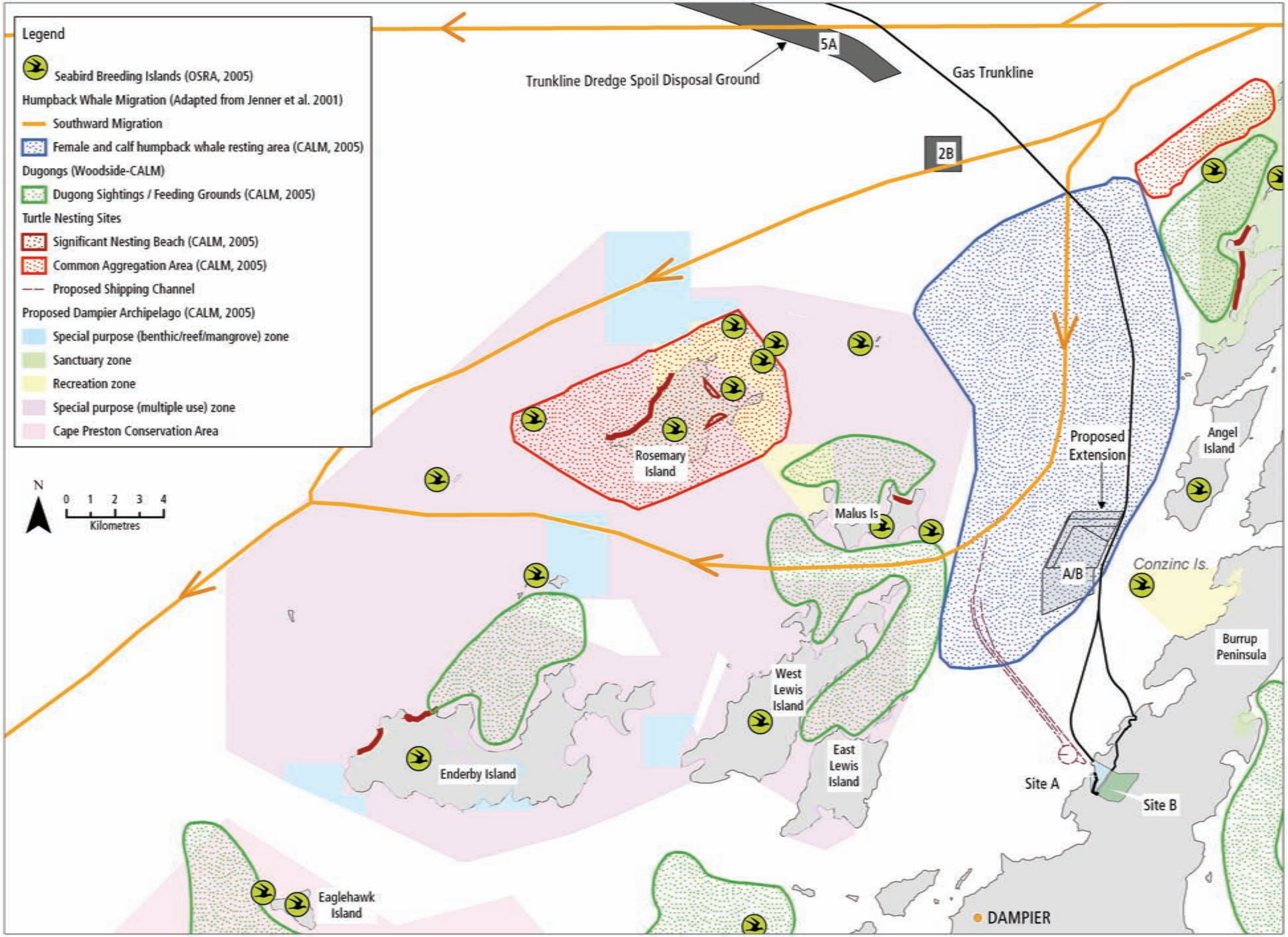
Humpback whales are likely to migrate through spoil ground 5A on their southerly migration. Similarly, sea turtles may pass over the offshore section of gas trunkline on their migration between Barrow Island and Dampier Archipelago (**Section 6.3.5**). Dugong habitat and sea turtle aggregation areas are located approximately 12.4 km and 10 km away from the nearshore end of spoil ground 5A.

Table 7-24 Interactions Between Spoil Grounds and Marine Sensitivities

Environmental Sensitivity	Proximity of Spoil Ground to Sensitivity (km)					
	Spoil ground A/B	Spoil ground 2B	Spoil ground 5A	Spoil ground A/B	Spoil ground 2B	Spoil ground 5A
Humpback whale migration route (southern)	✓	✓	✓	2	0	0
Humpback whale female and calf resting areas	✓	×	×	0	3	7
Dugong habitat (significant sightings/ feeding areas)	×	×	×	4	8	12
Sea turtle aggregation areas	×	×	×	12	7	10
Seabird breeding islands	×	×	×	2	8	10
Coral reef (intertidal/ subtidal)	×	×	×	2	4	8
Macroalgae (subtidal reef)	×	×	×	1	6	10

*Source: Calculated using GIS tools and data sets presented in **Figure 7-10***

Figure 7-10 Marine Environmental Sensitivities in the Vicinity of the Pluto LNG Development



7.9.6 Summary of Dredging Methodology

The dredging programme will require a range of dredging vessels:

Trailer Suction Hopper Dredges: The vessels that will be used will vary between a trailer suction hopper dredge and a cutter suction dredge depending on the seabed conditions, geology and bathymetry. The trailer suction hopper dredge (approximately 130 m in length) will remove softer sediments that overlie bedrock and store the sediments onboard within internal hoppers. The vessel will then cease dredging to transit to a pre-determined spoil disposal site. Once at the spoil disposal site, spoil will be disposed of whilst the vessel is in motion via hopper doors at the bottom of the hull. The vessel will then transit back to the dredge location. It is anticipated that the dredging programme will require two trailer suction hopper dredges with some overlap in operations. The main sources of sediment release will occur from:

- over-flow of sediments during dredging at approximately 5–8 m below the water surface
- disposal of spoil from bottom-opening doors, at 5–8 m below the water surface.

The trailer suction hopper dredge will have an overflow point at the bottom of the hull for discharge of supernatant (excess water with entrained sediments generated during overfill of the hoppers).

Access to site: A fully laden jumbo-sized trailer suction dredge requires 11 to 13 m water depth to work efficiently (allowing for 1.5 to 2 m keel clearance). The initial water depth of the site (7 to 8 m CD) is insufficient for a jumbo dredge to operate. This means that either a smaller dredge will have to be mobilised to create the water depth required for a jumbo-sized dredge; otherwise, it will have to work its way in.

Scheduling conflicts: Once the overburden is removed to suitable depth the jumbo becomes more viable. The process of dredging however, would be limited to the progress of the cutter dredge crushing the calcarenite material. A jumbo-sized trailer operates at about twice the rate of the large cutter dredge. It is of great importance that material can be crushed quickly enough to keep the trailer occupied and for crushed material to be picked up quickly enough to optimise the crushing process (the cutter cuts material but places it back onto the seafloor). Verification that the design depth has been reached can not be achieved until the trailer picks up the material. Delays to the scheduling of the jumbo-sized trailer will reduce the cost benefits.

Availability: In the current market, very large dredging equipment may be difficult to procure. There are more midsize vessels available that are suitable for the dredging programme.

Environmental Impacts: The use of the jumbo trailer will have an effect on the amount of TSS created from propeller wash. Although a jumbo trailer would operate for a shorter period of time thus reducing the duration of sediment disturbance, the propulsion power of the jumbo trailer is significantly larger than the midsize vessel (jumbo trailer approx 25 000 kW compared to 12 000 kW for a medium size trailer and therefore a jumbo trailer is likely to suspend sediments at a significantly higher rate during the operation).

The above factors indicate that the dredging contractor will need to optimise the dredging programme to compensate for various constraints. It is unlikely the contractor will propose a very large trailer. Instead, a size within the range between a jumbo and a mid-size dredge may be deemed viable (at least for part of the dredging programme).

Cutter Suction Dredge: A large cutter suction dredge (approximately 125 m in length) is likely to be used to remove harder, consolidated material that the trailer suction hopper dredge is not capable of removing. The cutter suction dredge will most likely operate within the ship berth, where the material is concentrated. Spot removals further along the navigation channel may also be required. However, the cutter suction dredge will use retractable spuds and anchors for positioning and, therefore, will not contribute suspension of sediments via propeller wash. The cutter suction dredge will cut limestone rock and side-cast all of the material to just above the seabed for subsequent collection by the trailer suction hopper dredge. Therefore, all of the production would be initially discharged to above the seabed layer. These dredgers typically produce mixed size-fractions ranging from fine silts through to small rock fragments.

Dredging undertaken by the cutter suction dredge will clear access to any hard rock outcrops that may require drill and blast work. Cutter suction dredge operations are also anticipated for the shore crossing approaches of the gas trunkline.

Nearshore Drill and Blast Rig: This rig will comprise a self-elevating, non self-propelled, drilling platform. A support vessel will escort the rig and provide manoeuvrability. The drill and blast rig will target the deeper hard rock intrusions, if found, for the navigation channel, berth pocket and the gas trunkline shore crossing. This activity will involve drilling an array of small holes (15–30 cm diameter) with subsequent discharge of hole cuttings to the seabed. Drilling and blasting will fracture the rock generating a size-fraction ranging from fine particles of clay and silt to boulders. Noise associated with drill and blast operations is assessed in **Section 7.11**.

Backhoe Dredge: The fragmented hard rock from the drill and blast activities concentrated at the jetty berth and inshore sections of the navigation channel and gas trunkline options will be recovered by a vessel mounted backhoe dredge. A backhoe dredge utilises a large excavator arm equipped with an open bucket. The excavator will lift the fragmented material and deliver it to a moored hopper barge that will be towed to the disposal site. Materials produced by drill and blasting are expected to range from rock fragments to fine silts. The barge would be overflowed until it contains a sufficiently high load of sediments, resulting in the overflow of supernatants. Fine silts will contribute most of the sediments lost in the overflows. In addition, the barge will either be self-propelled or require a support vessel for movement. Consequently, propeller wash is also expected to be a source of suspension from this operation.

Consideration was given to using a 'jumbo-sized' trailer suction dredge (> 20 000 m^3 hopper capacity). Based on a situation where no restrictions in available water depth apply, the jumbo trailer suction dredge is cheaper per cubic metre than a medium size trailer suction dredge for both sediment dredging and crushed rock dredging. These cost implications become more apparent as the dredge spoil disposal ground(s) moves further away from the dredging site which is relevant to spoil ground A/B and the northern extension, and the deep water site 2B located outside of Mermaid Sound. However, there are a number of factors that outweigh but do not necessarily preclude, the use of a jumbo-sized trailer dredge as described below.

7.9.7 Trajectory and Fate Modelling for Sediment Plumes

7.9.7.1 Model Overview

The fate of sediments suspended by the proposed dredging operations has been simulated by APASA using the three-dimensional, sedimentation modelling system, SSFATE. This model computes TSS distributions and sedimentation patterns by predicting the transport, dispersion and settling of suspended sediments released into the water column using a random procedure (APASA 2006a). The model calculated concentrations additional to background levels ('above background'). Further modelling will be undertaken as part of the predictive forecasting described in **Section 7.9.16**.

The focus of the model is on far field processes (that is, immediately beyond the initial release jet) affecting the fate of suspended sediment. The model uses specifications for the suspended sediment source strength (that is, mass flux), vertical distributions of sediments and sediment grain-size distributions to represent the effect of different types of mechanical or hydraulic dredges, sediment disposal practices or other sediment disturbing activities such as jetting or ploughing for trunkline burial. Similarly, it takes into consideration seasonal, tidal and episodic variations in the prevailing water currents.

The model was then interrogated to calculate potential total concentrations by including measures of typical and more extreme background concentrations within Dampier Archipelago.

Modelling of hydrodynamic circulation within the Dampier Archipelago and Mermaid Sound was carried out using the three-dimensional hydrodynamic model, HYDROMAP. This model simulates the flow of ocean currents caused by astronomical tides, wind stress and bottom friction and has also been used to simulate the fate and effect of hydrocarbon spills (**Section 7.10**). Influences of astronomical tidal variations are specified from tidal constituent values that define the wavelength and amplitude of individual tidal constituents. Forcing due to wind shear has been calculated from wind measured at multiple locations, to represent a spatially-varying wind field. HYDROMAP has been widely applied to studies of hydrodynamic circulation and the fate of spills and discharges on the North West Shelf for several years, where it has proven to be reliable. Model validation for Dampier Archipelago was undertaken by comparison to current measurements from multiple locations (**Section 7.9.7.3**). The SSFATE outputs using current fields provided by the HYDROMAP model have been validated against physical measurement in international and local dredging studies including Langtry (2003) and Swanson et al. (2004). A validation of the SSFATE model for Dampier Archipelago was undertaken by hind-casting of a previous dredging operation where sedimentation rates were measured. This is detailed in **Section 7.9.7.3**.

The SSFATE model was used to simulate single dredging operations as well as multiple concurrent dredging operations, where more than one source of suspension generated overlapping plumes (APASA 2006a). **Figure 7-11** shows an example of a plume predicted for a single operation, in this case a trailer suction dredge operating around the proposed ship berth, under one set of conditions and represents the highest instantaneous concentration at any depth level below each grid cell in the model. **Figure 7-12a-c** shows an example of the net TSS concentrations from four concurrent operations along the navigation channel, namely: trailer suction hopper dredge, cutter suction dredge, backhoe dredge and drill and blast platform. The SSFATE model outputs in these plots present the TSS concentrations in vertical planes. The TSS example plots presented in this section includes TSS concentrations predicted at the surface, mid-water and near to seabed. In this example, each source of suspension is generating localised areas of high TSS concentrations, which are decreasing by an order of magnitude over distances of several hundred metres. These plumes interact over time in a stochastic manner to generate patches of higher and lower concentrations within a generally narrow plume, streaming away in the direction of the prevailing current. Due to the relatively narrow and variable position of the dispersing plume, exposure of sensitive receptors at more remote locations from the suspension sources is expected to be episodic rather than chronic.

Figure 7-11 Example of the Sediment Plume Expected from a Single Dredging Operation (Trailer Suction Hopper Dredge Overflow)

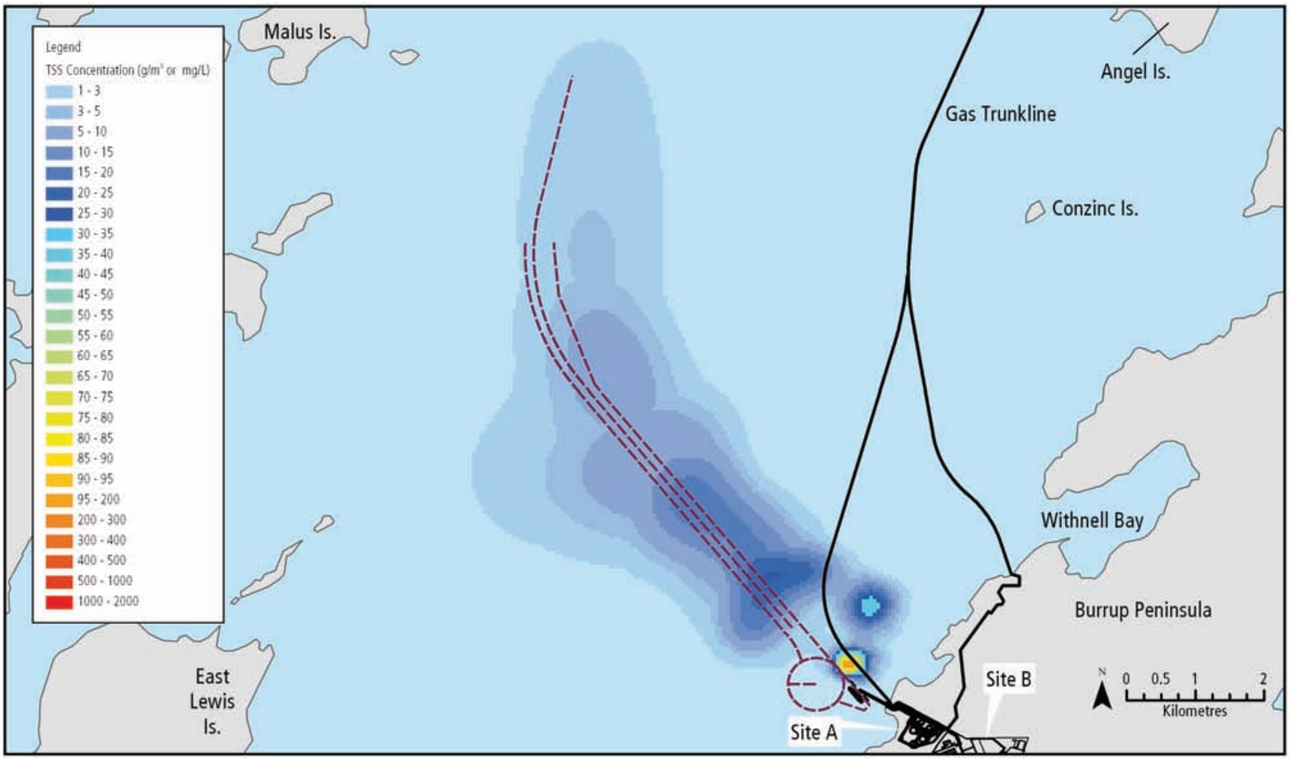


Figure 7-12a Example of the Combined TSS Concentrations Predicted from Four Concurrent Dredging Operations at Surface

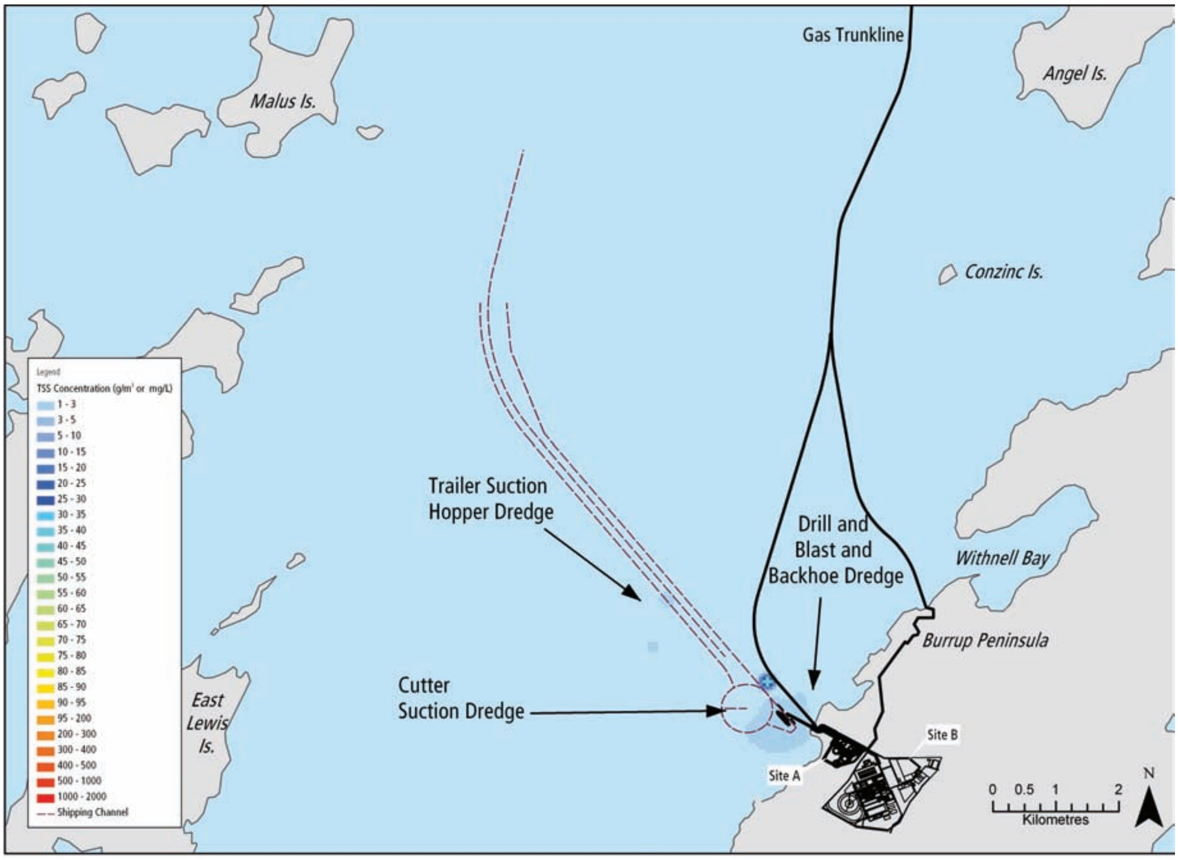


Figure 7-12b Example of the Combined TSS Concentrations Predicted from Four Concurrent Dredging Operations at Midwater

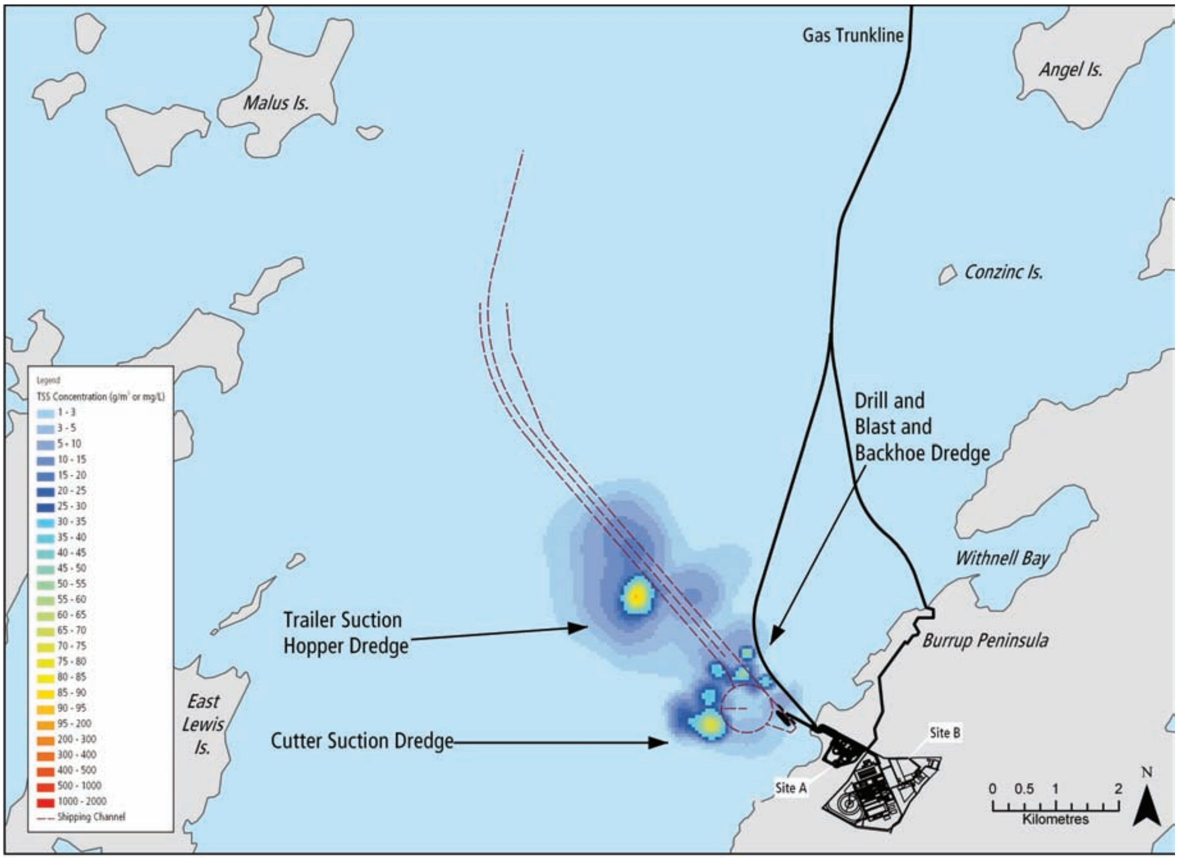
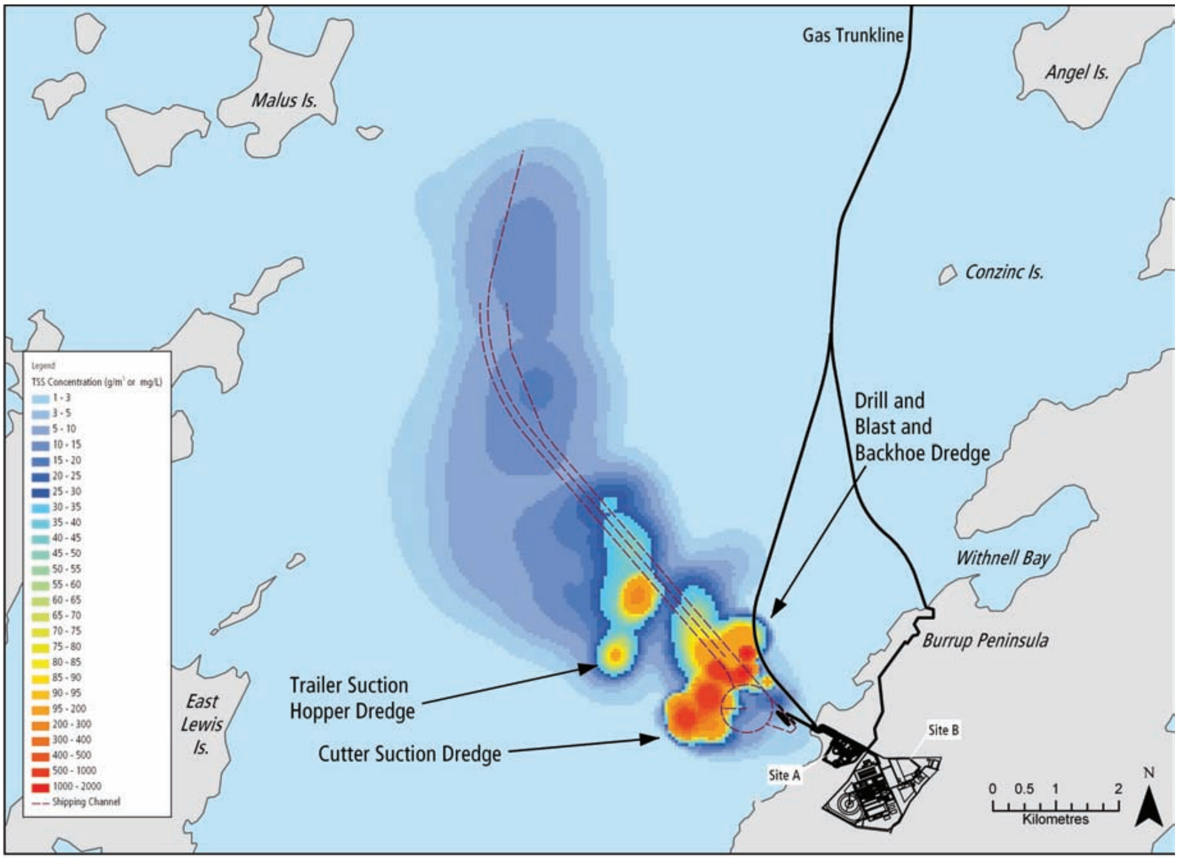


Figure 7-12c Example of the Combined TSS Concentrations Predicted from Four Concurrent Dredging Operations at Bottom



7.9.7.2 Scenarios Modelled

The sediment plume dispersion study (APASA 2006a) has comprised a series of modelling phases that have accounted for modifications to the dredging programme over time. These phases can be broadly defined as follows:

Phase 1: Modelling a Conceptual Dredging Programme

A conceptual dredging programme was developed and is described in detail in APASA (2006a). This programme was based on a number of assumptions, the key ones being:

- A conceptual and alternative navigation channel alignment were under consideration at the time of modelling and were located parallel to one another. The modelling focussed on simulating the fate and effects of suspended solids from the conceptual channel. Sensitivity testing was undertaken to assess the relative effects of relocating the dredging activities to the alternative navigation channel alignment.
- The dredging and spoil disposal programme would be 20 months in duration, involving multiple dredging activities and sources of sediment suspension. The conceptual plan broadly comprised:
  - trailer suction hopper dredging of overlying sediments from the navigation channel
  - disposal of overlying sediments collected by trailer suction hopper dredge into spoil ground A/B
  - cutter suction dredging and side casting of cut material at the turning basin and berth pocket
  - collection of cutter suction dredge material by trailer suction hopper dredge and subsequent disposal into spoil ground A/B
  - drill and blasting of dolerite rock at the berth pocket location
  - backhoe dredging to recover material released by drill and blast operations
  - disposal of backhoe dredge material from hopper barges into spoil ground A/B
  - trenching for burial of the gas trunkline.
- Dredging would be conducted on a 15 hour per day basis and would include three dredging and disposal cycles per day, followed by a resting phase of approximately nine hours when no new dredge-related suspension would occur.
- Sediment particle size distribution data for sediment suspended along the navigation channel, turning basin and berth pocket would be similar to those suspended by previous operations within Mermaid Sound (SKM 2004) and Geraldton (GEMS 2003).
- Dredge spoil would be disposed of into an extension to the existing spoil ground A/B for the duration of the dredging programme. Comparison of spoil disposal into deep water spoil ground 2B was also undertaken but for selected months.

Further information on the conceptual model assumptions is provided in **Section 7.9.7.4**.

The entire conceptual dredging programme was modelled for the period of dredging and dredge spoil disposal. The modelling of the activities described above comprised of the following activities:

- Simulation of each of the operations was undertaken that represented a source of sediment suspension during each month of dredging. These simulations used samples of current data from the month of the year that these operations were programmed to occur. For example, under the conceptual dredge programme, trailer suction hopper dredging of sediments overlying the navigation channel would occur from January 2008 through to December 2009 under the conceptual dredge programme. Therefore, simulations of sediment suspension associated with this operation were completed for 12 months using current data spanning this period. The location of the dredging was varied over time based on calculations for the progress of dredging commencing from the inshore end.
- Calculations of the cumulative outcomes of each of the coinciding operations during each month and for the full operation were performed.
- Analysis was undertaken of the outcomes of sediment modelling to report expected sedimentation rates and time-histories of suspended sediment concentrations at sensitive receptors. Calculations of cumulative daily sedimentation loads were developed for this assessment over short term (one day), medium term (five days) and long term (15 days) durations based on acute, medium and chronic thresholds for coral impact.

Phase 2: Sensitivity Testing to Account for Refinement in the Dredging Programme

The outputs from Phase 1 provided a predicted pattern of monthly sedimentation and suspended solid concentrations over the duration of the dredging operation within Mermaid Sound, based on the conceptual navigation channel alignment. The conceptual programme was subsequently refined to include the assumption that dredging and dredge spoil disposal may be undertaken on a 24-hour basis (**Section 7.9.7.4**). At this time, the results of sediment sampling along the proposed navigation channel became available and were used to test the sensitivity of predictions to variations in the grain size over the observed range (**Figure 7-6**).

Additional modelling activities undertaken at this stage to support the outputs of Phase 1 included:

- Sensitivity testing of model predictions for propeller wash (**Section 7.9.7.7**), dredging overflow and sediment disposal (APASA 2006a), given a change from 15 hr/day to 24 hr/day operations. The outputs from this were used to determine the significance, if any, resulting from an increase in the daily dredging duration on TSS concentrations and sedimentation rates at sensitive receptor sites.

- Sensitivity testing to quantify the influence of grain size on the spatial distribution of sediment plumes from spoil disposal activities into spoil ground A/B, given the range collected from the navigation channel. The grain size sensitivity test outputs are presented in APASA 2006a and considered four different sediment mixtures.

Phase 3: Partial Modelling of a Modified Dredging Programme

The conceptual dredging programme was subsequently modified and extended in duration by a further four months to a total of 24 months (excluding blasting of igneous rock, if required). As part of the modified dredging programme, the navigation channel, turning basin and berth pocket were relocated approximately 400 m to the south of the conceptual location. The key modifications to the conceptual dredging programme, modelled in Phase 1 comprise:

- Dredging and dredge spoil disposal is predicted to require two trailer suction hopper dredges operating concurrently for approximately 15 months of the dredging programme.
- Following consultation with the DPA, it was determined that spoil ground A/B had limited capacity to accept dredge spoil. Spoil would therefore be disposed of into selected areas of spoil ground A/B and a northerly extension of this ground for up to eight months duration, as described in **Section 7.9.4** and **Figure 4-12**. The remainder of the spoil would be disposed into deep water spoil ground 2B. Based on the results of modelling undertaken in Phases 1 and 2, which indicated that exposure to sensitive reef habitats surrounding spoil ground A/B was more likely for discharge of finer sediment mixtures, the modified plan was to direct the bulk of finer sediments to deep water spoil ground 2B to minimise potential impacts.

The scenarios presented in this section reflect the current dredging programme and include outputs from all phases (Phases 1–3). **Table 7-25** provides a summary of the scenarios presented in this section and used to assess environmental impacts. Additional modelling outputs, particularly for the Phase 1 modelling are provided in APASA (2006a). The Phase 1 modelling provided monthly (30 day) cumulative sedimentation and TSS plots representing multiple sources of the conceptual dredging and dredge spoil disposal programme. These outputs were used to guide the Phase 3 modelling in terms of identifying particular seasons during which benthic habitats within Mermaid Sound are predicted to be impacted by effects from elevated TSS and sedimentation concentrations.

All model outputs presenting TSS and sedimentation concentrations in this section of the Draft PER (Phases 1–3) are based on dredging along the conceptual navigation channel superimposed with the alignment for the most recent design of the navigation channel.

7.9.7.3 Model Validation

Both HYDROMAP and SSFATE models have been validated to determine the reliability of model predictions presented in this Draft PER and the supporting sediment plume dispersion study (APASA 2006a). This validation exercise was undertaken as part of a wider validation study entitled *Validation Study of the Pluto LNG Development Dredging Programme* (APASA and SKM 2006), which simulated the dredging of the NWSV LPG jetty expansion in 1994 and compared the model outputs to field monitoring of sedimentation and coral health carried out before, during and after dredging.

HYDROMAP Validation

HYDROMAP predictions of wind and tide-driven circulation within the Dampier Archipelago and Mermaid Sound were validated by hind-casting periods corresponding to independent measurements of water currents between September and November 1981. In doing so, the model configuration and specification of tidal forcing were identical to the set-up applied to forecasting sediment plume dispersion from the proposed Pluto LNG Development dredging operations (APASA 2006a) and hydrocarbon spill modelling (APASA 2006b), except that wind data corresponding to the current sample times were sourced from the NCEP/NCAR model re-analysis archives and this data represented wind conditions as spatially uniform over the model domain, rather than the spatially-varying wind conditions applied to the sediment plume dispersion study for the Pluto LNG Development (APASA 2006a). Despite this, the wind data was considered suitable for testing the general performance of the model in describing circulation patterns within the study area (APASA and SKM 2006).

The results of tidal modelling at a location within Mermaid Sound were compared to recorded tidal data at the same location for the same period and showed close alignment (**Figure 7-13**). The results indicate that the tidal data supplied at the boundary of the model was suitably accurate and that the model accurately predicted the spatial propagation of the tidal waves through the model domain within an accuracy of 10-20 cm (APASA and SKM 2006).

In addition to tidal validation simulations, near seabed current validations were conducted. Currents predicted at a location within Mermaid Sound and compared to actual measurements at the same location and for the same period showed good correlation in terms of the magnitude, direction and timing of most periods of observed current flow (**Figure 7-14** and **Figure 7-15**). There were some errors in the magnitude and direction of the currents, mostly during the neap tidal phase, when tidal forces were weakest (APASA and SKM 2006). This result indicates that errors are mostly due to the representation of wind forcing, possibly due to errors in the NCEP/NCAR wind data. Despite this, scatter plots indicate a linear correlation between the predicted and observed currents along both the north-south and east-west axis. Comparisons at other sites within Dampier Archipelago exhibited a similar pattern of correlation between predicted and observed currents (APASA and SKM 2006), indicating that the model is suitably accurate over the wider study area.

Table 7-25 Summary of Modelling Outputs Used in Assessment

Modelled Scenario	Modelling Phase	Purpose/ Application in Assessment	Section Discussed In Draft PER
Dredging Scenarios			
Propeller wash re-suspension from trailer suction hopper dredge during transit to spoil ground A/B	Phase 1	Provides an example and indication of TSS concentrations from this type of activity.	Section 7.9.7.7
Propeller wash sensitivity testing based on 15 hr v 24 hr dredging programme	Phase 2	Used and tested for build up of TSS concentrations over subsequent days of operation to distinguish the impact of a change in dredging duration on TSS concentrations from this source.	Section 7.9.7.7
Trailer suction hopper dredge overflow from dredging of berth pocket, turning basin and navigation channel	Phase 1	Used to give an indication of TSS and sedimentation concentrations from this type of activity under varying conditions and given movement of the suspension source over time.	Section 7.9.7.8
Cutter suction dredge operating at the berth pocket	Phase 1	As above for cutter suction dredging	Section 7.9.7.8
Backhoe dredge operating at berth pocket	Phase 1	As above for backhoe dredging	Section 7.9.7.8
Backhoe dredge operating at Holden Point for installation of the gas trunkline	Phase 1	As above for the trunkline crossing	Section 7.9.7.10
Trailer suction hopper dredge operating at turning basin and berth pocket	Phase 3	Used to represent cumulative sedimentation and coral loss estimates	Section 7.9.7.8
Dredge Spoil Disposal Scenarios*			
Disposal of fine material from trailer suction hopper dredger into northern portion of spoil ground A/B (area CDG) in winter (June)	Phase 3	TSS and sedimentation plots for 30 days disposal to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.9 Section 7.9.10.4
Disposal of coarse material from trailer suction hopper dredger spoil into ground A/B (area CDHIEF) and northern extension (area ABCD) in summer (Jan-Feb)	Phase 3	TSS and sedimentation plots for 30 days disposal to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.9 Section 7.9.10.4
Disposal of coarse material from trailer suction hopper dredger into spoil ground A/B (area CDHIEF) and northern extension (area ABCD) in transitional period (April-May)	Phase 3	TSS and sedimentation plots for 30 days disposal to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.9 Section 7.9.10.4
Disposal of spoil from trailer suction hopper dredger into spoil ground 2B in summer (November)	Phase 3	TSS and sedimentation plots for 30 days disposal to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.9 Section 7.9.10.4
Disposal of spoil from trailer suction hopper dredger into spoil ground 2B in winter (June)	Phase 3	TSS and sedimentation plots for 30 days disposal to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.9 Section 7.9.10.4
Trailer suction dredging along the offshore gas trunkline route (depths 20–50 m) with sidecasting to the seabed	Phase 1	TSS and sedimentation plots for 30 days operation to assist in determining predicted coral losses and impacts to other biota and users	Section 7.9.7.10

** For each of the scenarios modelled, corresponding TSS and sedimentation time series plots were developed to represent predicted TSS and sedimentation concentrations over the short term (30 days) at sensitive receptors.*

Figure 7-13 Comparison of Tidal Elevations Predicted by HYDROMAP based on Propagation from Model Boundaries and Expected from Data Measurements at a Single Location within Mermaid Sound

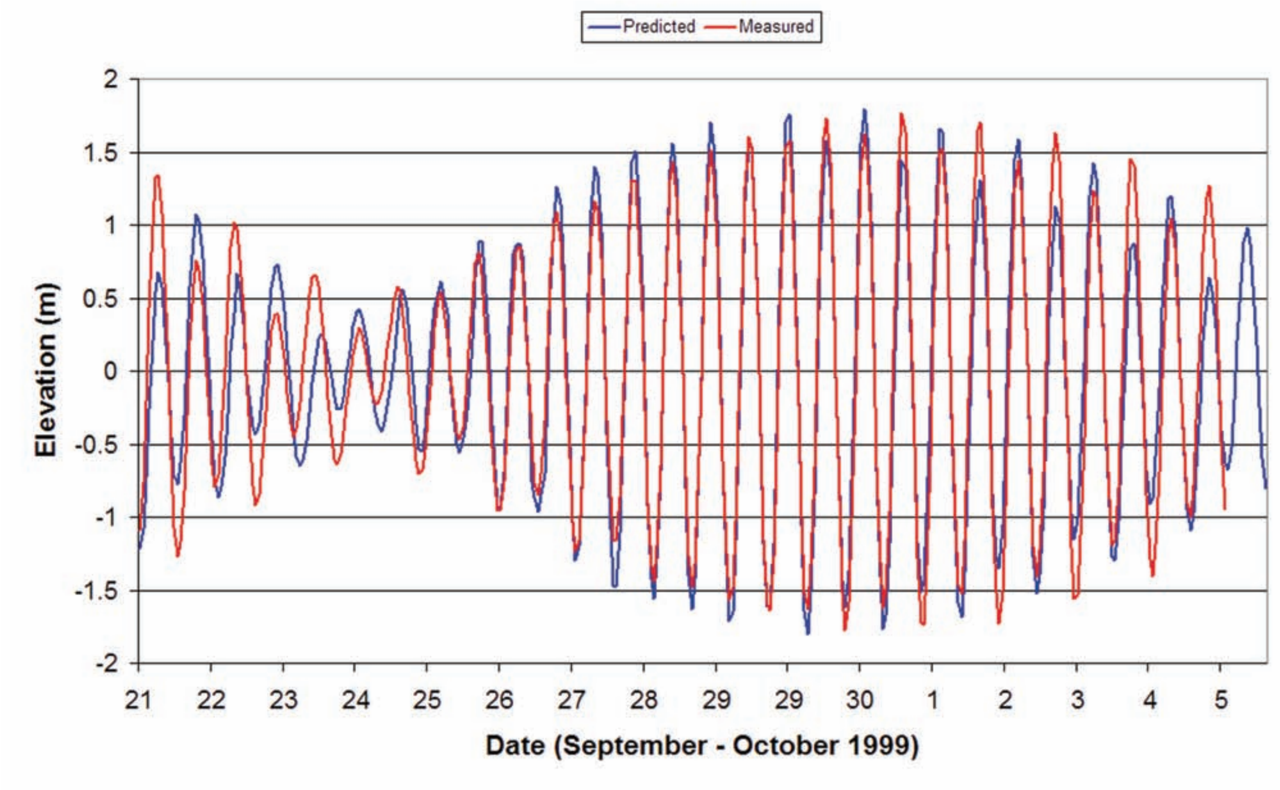


Figure 7-14 Time Series Plot Comparing Measured and Predicted Near Seabed Currents at Site DA1 in the East-West Direction

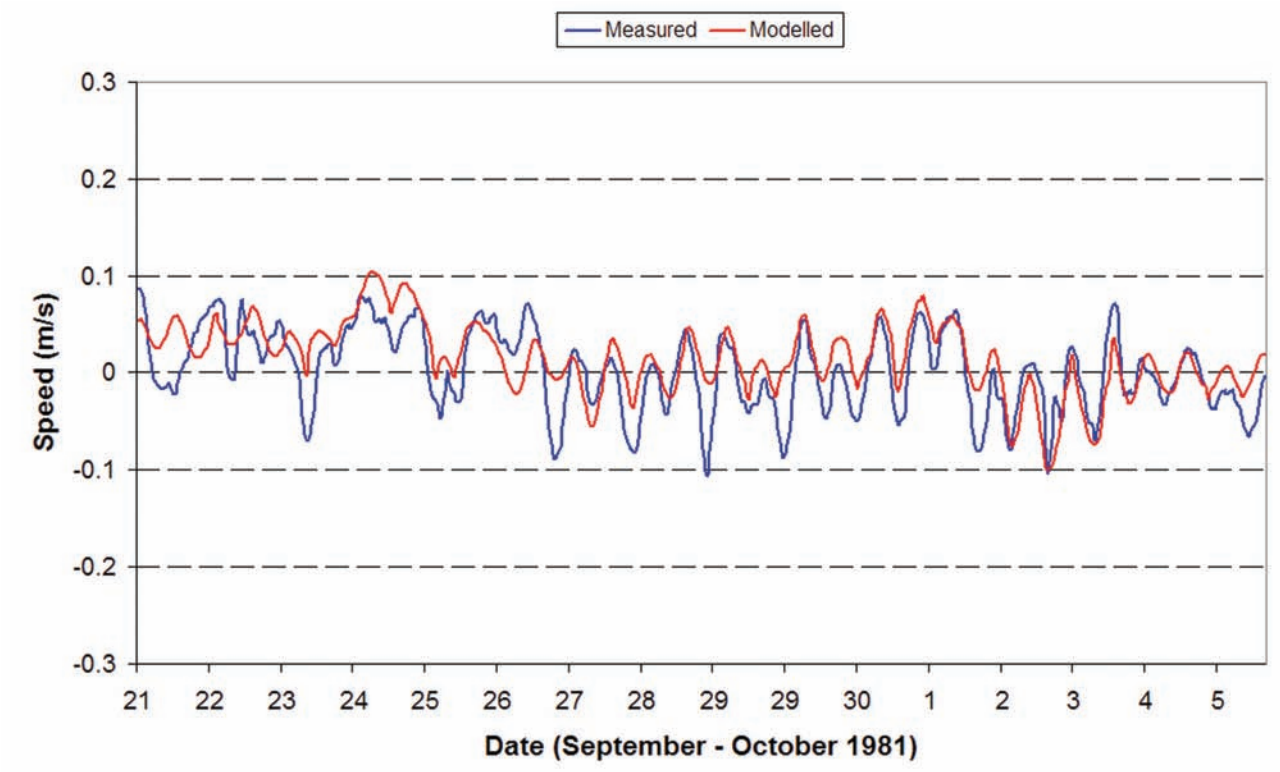
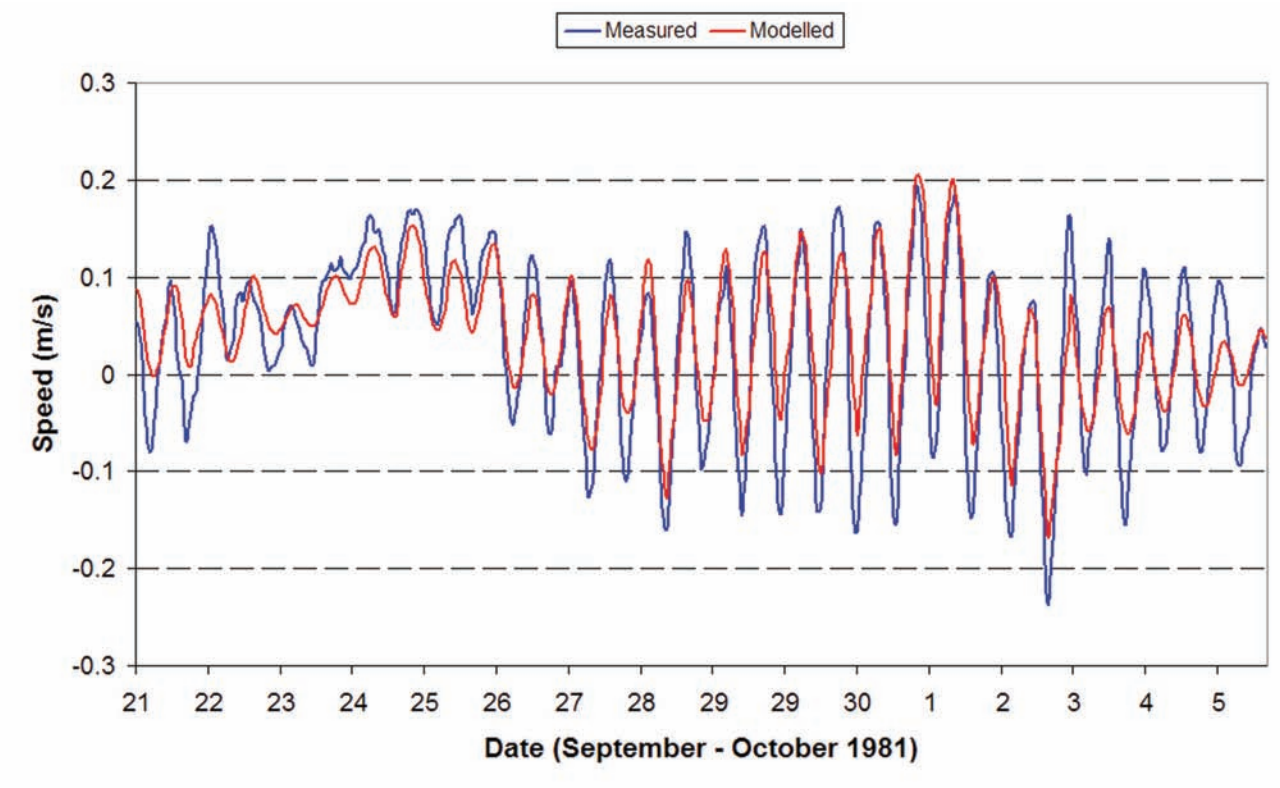


Figure 7-15 Time Series Plot Comparing Measured and Predicted Near Seabed Currents at Site DA1 in the North-South Direction



SSFATE Validation

The SSFATE model was validated by hind-casting the dredging operations carried out in March 1994 by the NWSV as part of the LPG jetty installation and comparing predicted outcomes for sedimentation to measured data. Sediment mixtures were based on those reported from previous operations in Dampier Archipelago (SKM 2004) and included sensitivity tests using variations in sediment mixtures anticipated for the area, as described in APASA 2006a.

The dredging operation was the subject of a monitoring study (LDM 1995; ECOS Consulting 1996) which involved measurements of sedimentation rates at six neighbouring sites prior to (five surveys), during (one survey) and after (one survey) the dredging operation. Details of the dredging operation are summarised in LDM (1995) and ECOS Consulting (1996).

Simulations of the 1994 dredging operation indicated a localised sedimentation footprint, centred along the dredge pocket with the main migrational axis running parallel to the shoreline of the Burrup Peninsula. The model indicated an exponential decrease in cumulative sediment concentrations with distance. Of the six monitoring sites, only two sites that were located immediately adjacent to the dredge pocket area (ChEMMS I and C2) experienced elevated sedimentation levels. SSFATE predictions for above-background sedimentation rates at monitoring sites ChEMMS I and site C2, correctly reflected the higher rate of sedimentation observed at these locations, during dredging (**Table 7-26**).

Correlation between estimates at both sites was highest for simulations that used relatively fine sediment mixtures. For instance, the mean background sedimentation at ChEMMS I over the last five days of dredging was predicted by the model as 416 + 187 g/m2 d-1, given the operation suspended a high proportion of fines by mass as 55% clay and fine silt), which closely matched estimates from sediment traps (**Table 7-26**). Model estimates for sedimentation at site C2 were marginally higher than estimated from sediment traps based on the finer mixtures but was of the correct order of magnitude (**Table 7-26**). It should be noted that sediment traps sample over a small area (tube diameter of 20 cm) whereas the model reports estimates averaged over larger areas. Given that the monitoring sites were positioned at a point where the model predicted a sharp gradient of sedimentation, this level of discrepancy can be attributed to small variations in the placement of the output point.

Overall, the results indicate that combination of the HYDROMAP and SSFATE models provides realistic predictions for the spatial distribution of sedimentation rates generated by dredging operations.

Further information on the model validation study can be sourced in APASA and SKM 2006.

Table 7-26 Comparison of Estimated Sedimentation Rates at ChEMMS I and C2 for Sediment Trapping and SSFATE Simulation

Monitoring Site	Estimate from Sediment Traps (Above Background)[1]	Sediment Mixture [2]	SSFATE Estimate Above Background (Mean + Standard Deviation)
ChEMMS I	418	D	416 + 187
		A	312 + 270
		C	119 + 51
C2	225	D	371 + 243
		A	287 + 307
		C	125 + 64

Note 1: Estimate of the sedimentation during dredging using trap gear, and corrected for background sedimentation. Assumes background of 33 g m-2 d-1, based on average sedimentation measured at all other sites during this period.

Note 2: Refer to APASA 2006a for description of sediment mixtures

7.9.7.4 Model Assumptions

Dredge Cycle

The example modelling (Phase 1) outputs for TSS and sedimentation along the navigation channel, turning basin and berth pocket are based on 15 hour dredging operations. This assumed three dredging and disposal operations would be conducted on a 15 hr/day basis and included three dredging and disposal cycles per day, followed by a resting phase of approximately nine hours when no new dredge-related suspension would occur. An alternative dredge programme that was subsequently considered, and now represents the base case, is 24 hr/day dredging operations with five dredging and disposal cycles per day.

Sensitivity modelling for propellar wash (Phase 2) was conducted to compare 15 and 24 hour operations to identify implications of longer operations each day (refer to **Section 7.9.7.7**).

Simulation of dredge spoil disposal operations into spoil ground A/B and a northern extension of this ground as well as into the deep water spoil ground 2B are based on 24 hour operations (Phase 3). The disposal operations represent one of the main sources of sedimentation from the dredging programme therefore a worst case 24 hour operation has been applied to simulate dredge spoil disposal to assist in determining cumulative impacts.

Particle Size Composition

The composition of material that is suspended within the water column will influence turbidity and sedimentation rates as well as the spatial extent of plumes and sediment piles. Grain size distribution data from previous dredging operations within Mermaid Sound (SKM 2004) and other ports, namely Geraldton (GEMS 2003), were used in the Phase 1 modelling to best replicate the anticipated material along the proposed navigation channel. The data from Geraldton (GEMS 2003) was used to represent sediments suspended from cutter suction dredging into limestone and the data from Dampier Port (SKM 2004) was used to represent sediments suspended from trailer suction dredging overflows and disposal operations. A conceptual sediment profile for the dredging channel was used to establish the depths of different sediments, and represented a basis for determining material composition along the navigation channel.

Additional modelling (Phase 2) was also undertaken when data from sampling along the proposed Pluto LNG Development navigation channel became available. This data represents the basis for sensitivity testing undertaken for cumulative simulations (Phase 3) of dredging and spoil disposal operations presented in **Section 7.9.7.9**.

Sediment Settlement Rates

The settling of mixtures of particles is a complex process due to interaction between different particle size classes, some of which tend to be cohesive and clump together. This process results in larger particles forming that have different fall rates than would be expected from their individual sizes (APASA 2006a). Enhanced settlement rates due to flocculation and scavenging are particularly important for clay and fine-silt sized particles and these processes were incorporated into the SSFATE model (APASA 2006a). The model has used specifications for the representation by five sediment size classes: coarse and fine sands, coarse and fine silts and clays (**Table 7-27**).

Sediment Suspension Rates

Various dredging activities will result in the re-suspension of sediments. The approach adopted has been to represent each individual source of sediment suspension and to combine the resulting sediment plumes and deposition fields from operations that would coincide to produce overlapping fields of effect (that is, cumulative effects). The mass flux, size composition and initial vertical distribution of sediments in the water column can be expected to vary considerably with particular dredge types, dredging practices, the nature of the sediments being worked, the presence of debris and local

Table 7-27 Grain-Size Classes, Sinking Rates and Suspension Velocities Applied by SSFATE

Classification	Passing Size (μm)	Sinking Rate (m/s)	Critical Suspension Velocity (cm/s)
Clay	2	0.0008	0.30
Fine Silt	20	0.0023	3.0
Coarse Silt	50	0.0038	7.0
Fine Sand	200	0.0106	15
Coarse Sand	2000	0.10	-

Source: APASA 2006a

metocean conditions, amongst other factors. This variation will affect the concentrations of suspended sediments and rates of sedimentation at surrounding locations.

Each of the dredging operations will be transient, that is, each dredge will move both within a day and between days. Rates of movement will not be uniform but will vary among operations and with the volume of material to be removed from each location. This was accounted for in the modelling by specifying sources of suspension that moved as a product of the production rate expected for the particular equipment type and the cross-sectional area of the material to be removed from different sections along each dredge path. Therefore, moving rates were slower for a particular dredge type over sections that were deeper and/or wider to represent the longer time that the suspension will be from these sections. For wide-ranging operations such as the trailer suction hopper dredge along the navigation channel, this approach accounted for the likely position of the operations during each season, and thus the consequence of the sedimentation source relative to seasonal trends in drift trajectory.

Rates of re-suspension and initial vertical distribution set up by the suspension sources are summarised in **Table 7-28**. The re-suspension rate is calculated as a proportion of the production rate, where the production rate is the mass of the sediments removed over time. Published re-suspension rates from trailer suction hopper dredge operations, with overflow, range from 0.0003 to 0.33% of the production rate (APASA 2006a). As a conservative approach, a rate of 0.3% has been applied to the modelling for the overflow phase.

7.9.7.5 Model Influences

Sediment plume behaviour and dynamics can be influenced by a number of factors including seasonality (prevailing winds and current directions), daily tidal movements (flooding and ebbing tides) and sediment grain size distribution:

- Seasonal influences on dredging operations: The direction of the drift currents will have a relatively strong influence on the behaviour of sediments suspended within the water column. Winds are generally from the north-east to the south during May to August (winter months) and from the south-west to north-west during October to March (summer months) and these winds impose some effect on the prevailing current directions. It can therefore be anticipated that the Burrup Peninsula and islands bordering the eastern side of Mermaid Sound will be more exposed to the effects of sediment plumes during summer months and that the level of exposure will lessen during the winter months. This effect is further discussed in **Section 7.9.7.9**.
- Tidal Variations: In addition to the influences anticipated from seasonal hydrodynamic patterns, the behaviour of sediment plumes on a daily basis will be affected by semi-diurnal tidal movements and variations in tidal magnitudes between spring and neap tides. In general, modelling indicated that wind effects on sediment transport will be greater during neap tides. The effect of tidal movement on sediment plume behaviour from the same dredging operation is presented in **Figure 7-19** to **Figure 7-20**.
- Grain Size Distribution: As outlined previously, grain size distribution will affect the behaviour of sediment plumes and this is discussed further in **Section 7.9.7.9**.

Table 7-28 Sources of Suspension, Re-Suspension Rate and Initial Vertical Distribution

Dredge Activity	Suspension Source	Re-Suspension Rate	Data Source for Initial Vertical Distribution
Non-overflow period	Propeller wash	0.1% in <10 m water depth 0.05% in > 10 m water depth	Damara 2004
Overflow period	Propeller-wash and overflow of fines	0.3%	Swanson et al. 2004 and Hays and Wu 2001
Transit	Propeller-wash	0.1%	Damara 2004
Discharge	Disposal from hoppers	100% less losses	Swanson et al. 2004

Source: APASA 2006a

The mobilisation (also referred to as resuspension) of sediments from the seabed into the water column is a normal process and an important component of particulate cycling in nearshore waters. For sediment particles to be mobilised from the seabed, the stress imparted by water movement must exceed a critical shear stress. As current velocity increases, the energy imparted on sediment increases until at some point, the critical shear stress is exceeded and the particle is mobilised. The critical shear stress required will vary depending on the particle size, density and shape and whether the sediment grains are cohesive or cemented (Hemer et al. 2004).

Smaller particles require less energy, and hence lower current velocity, to be mobilised from the seabed than larger particles. Consequently it is typically the case that finer particles will be lifted from the seabed first and remain in suspension longer than coarser particles leading to a potential to winnow sediments, leaving coarser sediments, behind if transport is consistently away from the site, or conversely, lead to an accumulation of fines in areas where currents dissipate. The particle size distribution of sediments on the seabed near to Holden Point, illustrated by **Figure 7-6** indicates that the seabed is comprised predominantly of fine particles; 55% of seabed particles (by mass) are less than 30 µm diameter, 26% less than 70 µm diameter and 12% less than 100 µm diameter.

The potential for mobilisation of particles of different size groups from the seabed at a given water velocity can be estimated by reference to empirical studies (for example, USACE 2001). Such studies have demonstrated that fine particles with diameter less than 75 µm can be mobilised at water velocities of about 0.22 m/sec (USACE 2001 in Damara 2004). However, cohesive sediments of the same grain size, such as muds and silt mixture, may require higher velocities of the order of 0.3 m/sec (Israel and Watt 2006).

Measurements of current velocity near the seabed (depth of 11 m) north-west of Holden Point in Mermaid Sound indicate that ambient velocities can reach 0.22 m/sec during spring tides. It is likely that in shallower waters wind generated waves would act incrementally to increase the water velocity at the seabed. Therefore fine materials, which represent more than 80% (by mass) of the surface sediments, on the seabed near Holden Point are subject to current velocities during spring tides that approach or exceed their critical shear stress for mobilisation.

The particle size distribution for sediments deposited to the seabed as a consequence of dredging operations has been estimated from a combination of direct observations of previous dredging in Mermaid Sound and theoretical values (APASA 2006a). **Table 7-29** provides a comparison of the measured in place seabed particle size distribution and the predicted particle size distribution of dredge generated sediments. It can be seen that there is very little difference in the distributions of particle sizes between native seabed sediments and dredge generated sediments. Consequently there will be minimal alteration of the particle size distribution of surface sediments near Holden Point as a result of dredging deposition. Therefore, the rate of mobilisation of sediments post dredging is very unlikely to be significantly different to the rate of mobilisation of sediments pre-dredging.

7.9.7.6 Model Summary

The sediment plume fate and trajectory modelling assessed the levels of suspended solids and sedimentation that would be generated by dredging and dredge spoil disposal operations both within and beyond the entrance to Mermaid Sound. The model calculated levels of additional TSS and sedimentation from multiple, simultaneous activities under varying environmental conditions. Conservative values were applied to the rates of discharge and the sediment grain size mixtures to ensure that the spatial effect of the operations were not underestimated. Sensitivity analysis was also applied to determine the effect of potential variations in the dredging programme or uncertainties associated with model input data. Conservatively high values of background TSS and sedimentation, based on field data for the study area, were then used to conservatively estimate total TSS and sedimentation.

The sedimentation model SSFATE was configured to represent the transport, sinking and deposition of sediments, given the three-dimensional circulation patterns in the study area. The model algorithms considered both vertical and horizontal mixing due to turbulence in the water column. The model also included a sedimentation algorithm that controlled the rate of sedimentation from the near-seabed water layer to the substrate layer, based on calculation of near-seabed shear stress and particle-size specific critical current velocities. This algorithm is included to produce realistic representation of sedimentation in the presence of current speeds that exceed the velocity that would cause suspension of sediment grains and thus result in

Table 7-29 Comparison of Particle Sizes in Seabed and Dredged Sediments (APASA 2006)

Size Group	Percentage of Particles (by mass)		
	Seabed Near Holden Point	From Cutter Suction Dredge Sidecast	From Trailer Suction Dredge Overflow
< 30 µm	55	56	60
< 70 µm	26	32	35
< 100 µm	12	8	5
> 100 µm	7	4	0

the ongoing resuspension and transport of particles in the near-seabed layer. Model outputs clearly demonstrate that this would be an important process in the setting of the sediment plume dispersion study. The clay and fine-silt particles, in particular, are predicted to migrate widely and over extended periods (days to weeks) during the simulations, forming a plume in the benthic layer, potentially reaching beyond the distance where particles would reach due to their sinking rate alone. Thus the modelling work considered ongoing resuspension and transport of the finer particles.

Prediction of resuspension of coarser material or movement of sediments by bedload transport was considered unnecessary because the sediments that would be contributed by the dredging were uncontaminated and of a similar size range to ambient sediments. Moreover, previous monitoring studies have highlighted the high levels of TSS and sedimentation that occur through natural events (for example, swells and storms) and other port operations (such as ship movements) and previous dredge impact modelling studies that examined resuspension by storm events (SKM 2004) had concluded that additional TSS and sedimentation that would be contributed by dredged material would be insignificant in relation to the wider resuspension and sedimentation budget of the study area.

7.9.7.7 Propeller Wash

Propeller wash from vessel operations along the proposed navigation channel is predicted to result in an evolving plume with concentrations of 50–80 mg/l immediately behind the vessel (refer to **Figure 7-16a-d**). Higher concentrations (100–200 mg/l) are predicted to develop near the seabed after the vessel has passed with the heavier particles settling on the seabed over a range of tens of metres from the source. Plumes of silt-sized particles are predicted to drift over hundreds of metres and be largely dispersed in the time between subsequent passages of the dredge (approximately 3 hrs between passages). **Figure 7-16a-d** presents an example time-sequence predicted for suspension along the navigation channel due to the passage of a trailer suction hopper dredge operations. Results are presented for TSS after 30 minutes (refer to **Figure 7-16a**), 50 minutes (**Figure 7-16b**), 70 minutes (**Figure 7-16c**) and 100 minutes (refer to **Figure 7-16d**) respectively for above background concentrations.

TSS concentrations are predicted to vary in a patchy manner, drift with the prevailing currents over time and decrease in magnitude between bouts of sediment displacement. **Figure 7-16a-d** shows a case where sediments are suspended into previously unaffected water. The plots show the highest TSS concentration at any depth during the duration of the modelled activity.

The time series plots indicate that 30 minutes after the trailer suction hopper dredge has transited along the proposed navigation route towards spoil ground A/B, TSS concentrations had decreased at the south-east end of the channel, but remained high at the north-west end that was more recently disturbed and is deeper, requiring a longer period of time for particles to settle out. After 50 minutes, the lighter fractions remain suspended over the navigation channel and begin to drift seaward on an ebbing tide. The predicted plume behaviour after 70 minutes suggests that the lighter fractions remain suspended and have dispersed further along the tidal axis. TSS concentrations generated by the trailer suction hopper dredge remain elevated (>80 mg/l) near to the seabed. The final image shown in **Figure 7-16d** shows that the trailer suction hopper dredge has returned along the channel, generating a second plume. The TSS concentrations generated at near seabed layer level along the channel are predicted to reach 100–200 mg/l. TSS concentrations in the near-seabed layer at the trailer suction hopper dredge station have decreased while the vessel was in transit to <30 mg/l.

Propeller Wash Sensitivity Testing

A comparison between TSS concentrations for 15 hour and 24 hour operations (that is, three dredge-transit-disposal cycles per day versus five) over a 3-day period is presented in **Figure 7-17** at a single location midway along the proposed navigation channel under a given set of environmental conditions. The green plots present TSS concentrations from 15 hour operations, whilst the blue plots present the TSS concentrations from 24 hour operations. In instances where dredging operations are restricted to day-time operations (that is, 15 hour operations), local TSS concentrations are predicted to drop to background levels during the non-dredging phase (that is, the night time hours). In the case of 24 hour dredging operations, 'spikes' or peaks of elevated TSS concentrations are predicted to occur more frequently leading to occasional higher spikes of TSS concentrations. However, the TSS concentrations are not predicted to build over time either under the 15 hour or 24 hour operation scenarios. TSS concentrations at the surface peaked at 100 mg/l in the surface and 300 mg/l in the bottom layer as short-lived episodes given either 15 hr/day or 24 hr/day operations. However, more spikes in TSS were expected over time with the 24 hr/day case.

Figure 7-16a Time-Sequence Showing Predicted Suspended Solids due to Propeller Wash during Dredging at Holden Point and Transit to and Disposal of Spoil into Spoil Ground A/B – 30 minutes

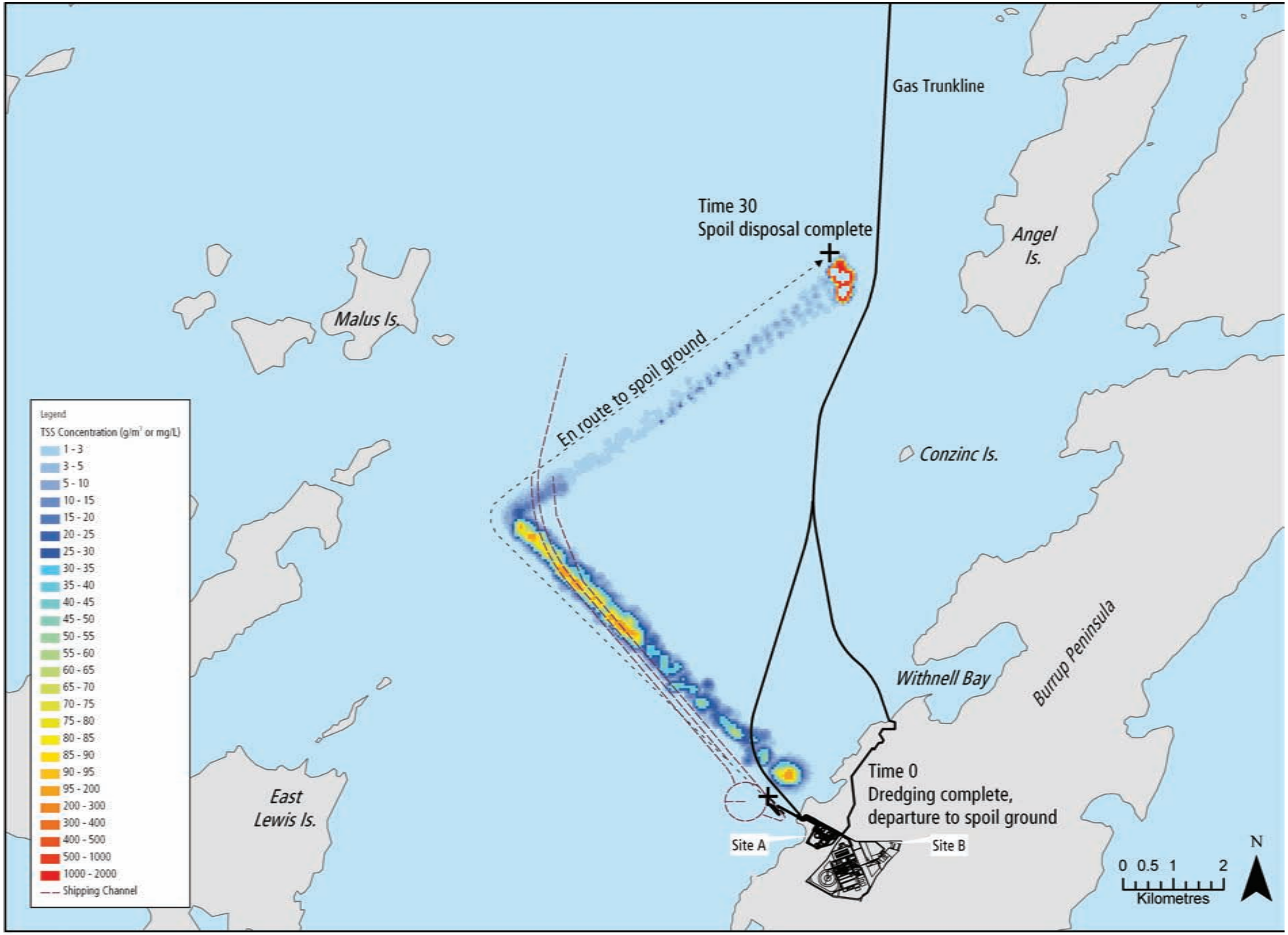


Figure 7-16b Time-Sequence Showing Predicted Suspended Solids due to Propeller Wash during Dredging at Holden Point and Transit to and Disposal of Spoil into Spoil Ground A/B - 50 minutes

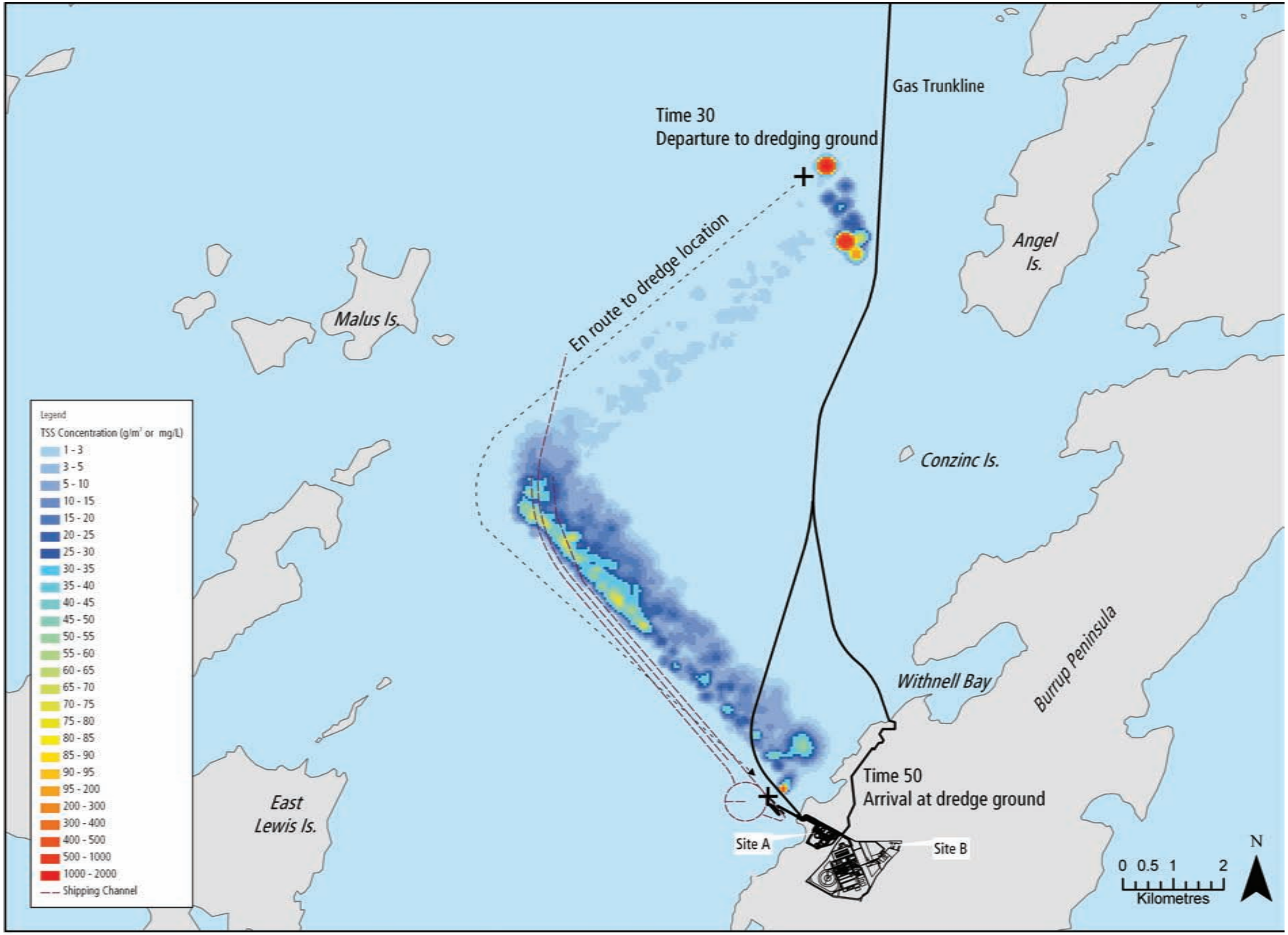


Figure 7-16c Time-Sequence Showing Predicted Suspended Solids due to Propeller Wash during Dredging at Holden Point and Transit to and Disposal of Spoil into Spoil Ground A/B - 70 minutes

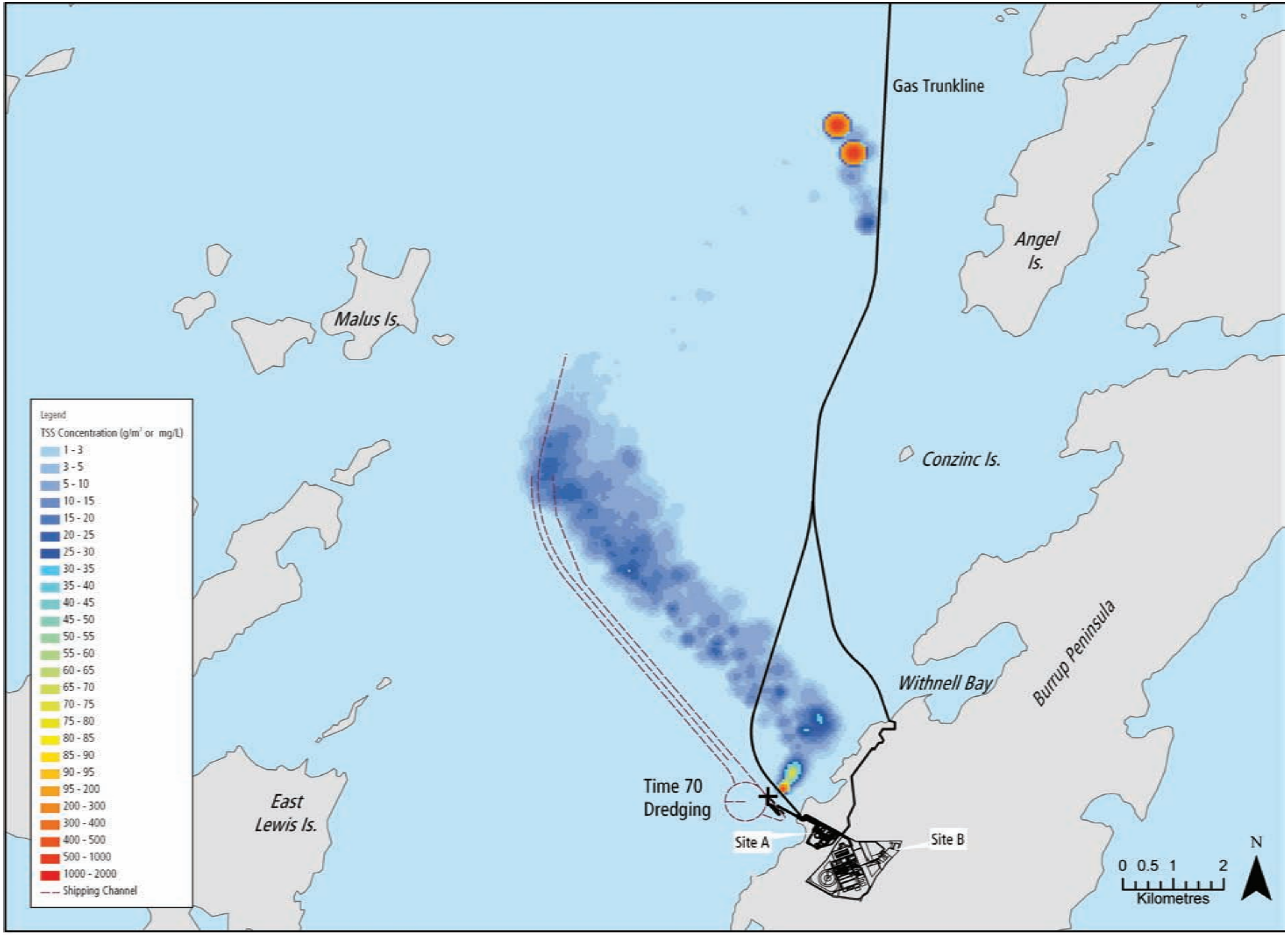


Figure 7-16d Time-Sequence Showing Predicted Suspended Solids due to Propeller Wash during Dredging at Holden Point and Transit to and Disposal of Spoil into Spoil Ground A/B - 100 minutes

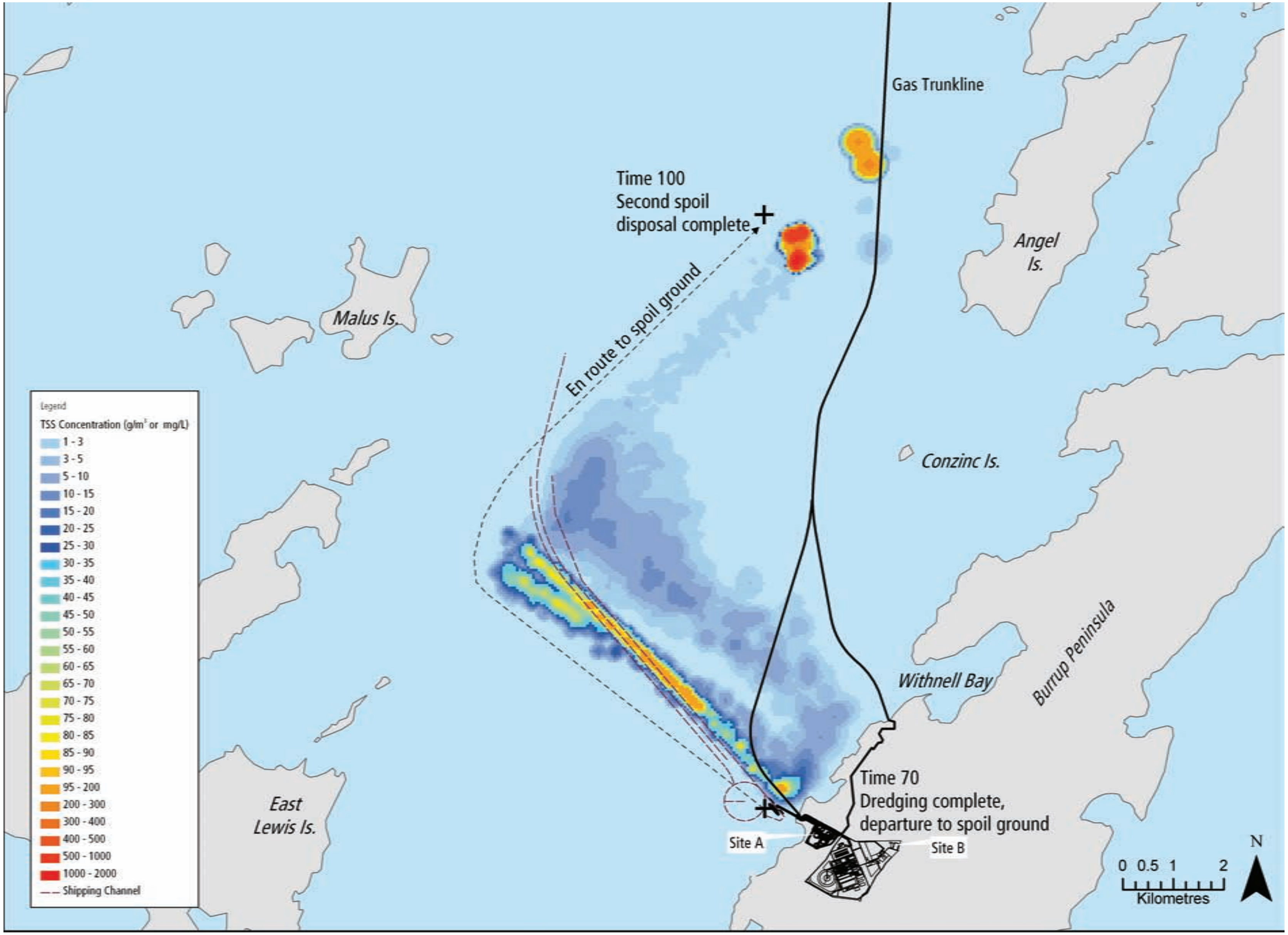
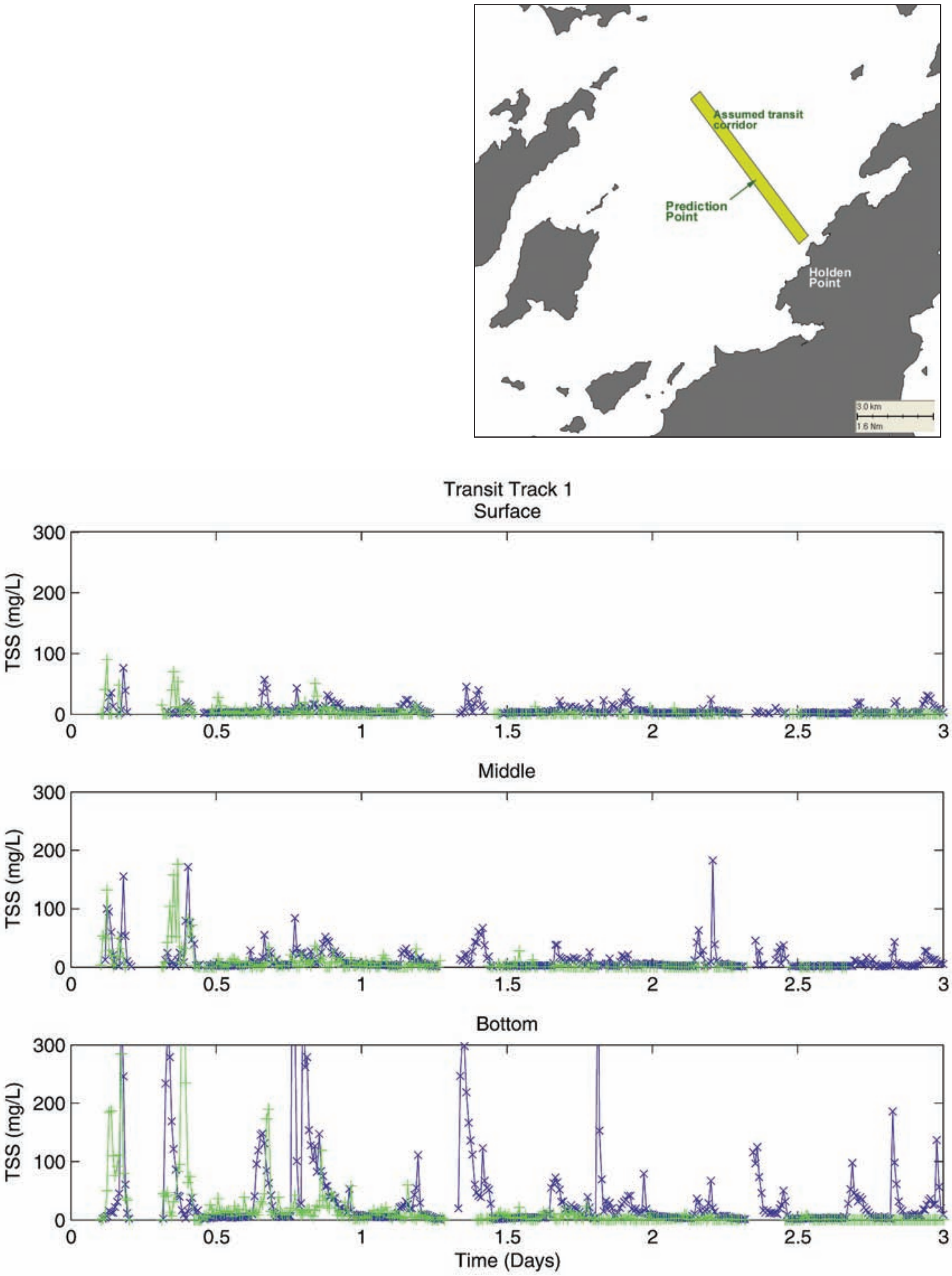


Figure 7-17 Predicted TSS Concentrations at Depth Intervals for 15 Hour Operations (5 Vessel Transits or 3 cycles per day) and 24 Hour Operations (10 Vessel Transits or 5 cycles per day)



7.9.7.8 Dredging Activities along the Proposed Navigation Channel, Turning Basin and Berth Pocket

The dredging of the navigation channel, turning basin and berth pocket will involve the following dredge vessels:

- trailer suction hopper dredge (up to two working in parallel)
- cutter suction dredge
- drill and blast rig (if required)
- backhoe dredge (if required).

Trailer Suction Hopper Dredge – Suspension of sediments associated with hopper overflow from the trailer suction hopper dredge is predicted to peak at concentrations of 25–150 mg/l within 50 m of the dredge vessel (**Figure 7-18**). TSS concentrations are predicted to vary over time due to variability in current velocities and dredge production rates. **Figure 7-19a-c** presents examples of the plume distribution predicted from trailer suction hopper dredge operations around the berth pocket, given variations in the prevailing currents. The figure shows the highest TSS concentration at the mid-water layer during the duration of the modelled activity.

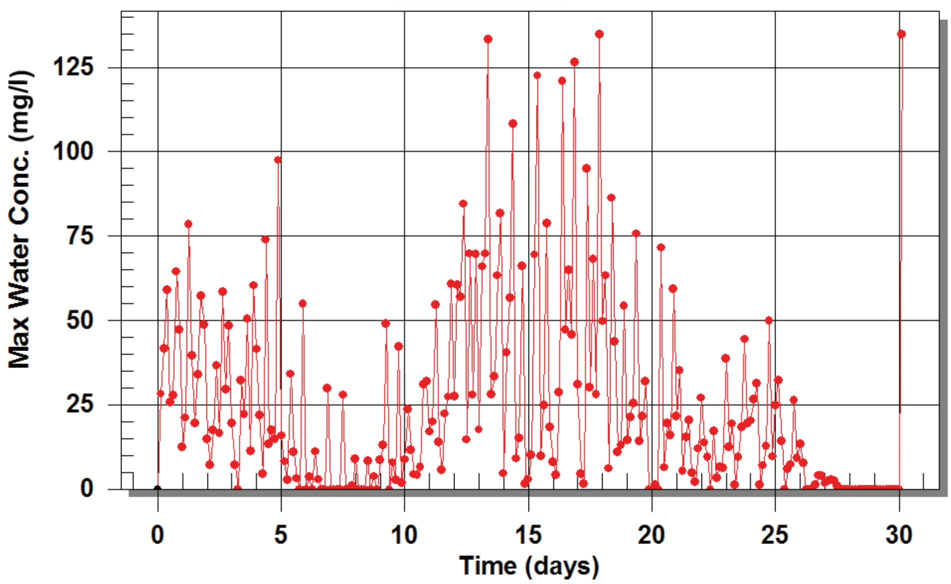
The plume trajectory and concentration of suspended sediments contained within the plume is sensitive to prevailing currents and variations in sediment load being generated resulting in patchy and localised distribution of the plume. The only sensitive habitats predicted to be affected by high elevations in TSS concentrations are those habitats close to Holden Point. These elevated concentrations are likely to be localised short-lived events, rather than building up over time or over a wider area.

Sedimentation due to trailer suction hopper dredge operations is predicted to be localised with concentrations and thicknesses decreasing exponentially along the tidal axis. Simulations indicate that approximately 10 km^2 of seabed is expected to receive >200 g/m^2/month (average of 6.7 g/m^2/day) and equivalent to a thickness of approximately 0.125 mm over the month. An area of seabed 4 km^2 is predicted to receive >1 kg/m^2/month (average of 33.3 g/m^2/day) which is equivalent to a thickness of approximately 0.5 mm for each month. The area of deposition was predicted to move with the dredge so there will be overlap between the areas affected during each month that would lead to localised accumulation centred about the dredge path. The dredge will progress more slowly over the months when operations are targeting the jetty berth and turning circle (because the width and depth are greater) so there will be higher total accumulation along the inner sections.

Cutter Suction Dredge – The cutter suction dredge operations will be concentrated nearshore at the jetty berth and turning basin and potentially near the midpoint of the navigation channel where harder material is likely to be encountered. Examples of TSS concentrations expected along the plume track generated by cutter suction dredge operations around the berth pocket under variable environmental conditions are presented in **Figure 7-20a-b**.

Plumes associated with cutter suction dredge operations in this area are predicted to frequently move into shallow water habitats over the duration of the dredge programme in comparison to trailer suction hopper dredge operations. This exposure was predicted to be episodic and related to prevailing wind and tidal conditions. Under neap tides and winds from the south-west to north-west, the predicted TSS concentrations at seabed level in Withnell Bay are predicted to remain above

Figure 7-18 Predicted TSS Concentrations Adjacent to Trailer Suction Hopper Dredge Overflow. Estimates are Based on 3 Hourly Intervals over 30 Days



25 mg/l for periods of days, peaking at 50–100 mg/l for short durations (hours) when strong onshore winds coincide with an ebbing neap tide. When winds are from the south-east during an ebbing tide the plume is predicted to move away from the coast (**Figure 7-20a**).

Sedimentation concentrations from cutter suction dredge operations are predicted to be higher than concentrations generated by the trailer suction hopper dredge, because dredged material will be temporarily left on the seabed, as opposed to being returned to the dredge vessel. Approximately 3–4 km^2 of seabed was predicted to receive > 10 kg/m^2/month (average of 333.3 g/m^2/day), equivalent to a thickness of 5 mm for each month. An area of seabed that is 10–12 km^2 in size is predicted to receive > 1 kg/m^2/month (average of 33.3 g/m^2/day), equivalent to a thickness of 0.5 mm for each month. These loads are predicted to centre over the discharge locations, with extensive overlap in the areas affected from month to month due to the concentration of cutter suction dredge work within the inshore section of the navigation channel. Simulations also indicated that a proportion of the finer sediments (predominantly fine silts) generated by cutting limestone will deposit outside of the turning basin and berth pocket and would not be subsequently collected. Thus, some modification of the sediment composition might be expected for the sediments surrounding the turning basin and berthing pocket. Deposition rates beyond the dredge pocket were predicted to decrease with distance from the source, but in some cases exceeded 500 g/m^2/month (average of 16.7 g/m^2/day) at a distance of 3 km along the main north-south tidal axis.

Drill and Blast Platform – Simulations of drill and blast operations suggest that only highly localised sediment plumes will occur, with low TSS levels ranging between 1 and 20 mg/l. Similarly, deposition concentrations are anticipated to be minimal (<50 g/m^2/month or 1.6 g/m^2/day) and equivalent to a thickness of 0.03 mm immediately around the rig and would not be distinguishable from background levels or from plumes generated by other concurrent dredging operations.

Backhoe Dredge – The operation of the backhoe dredge is likely to result in patchy and locally concentrated plumes of suspended sediment. Plumes >5 mg/l are likely to be generated at surface and >100 mg/l at seabed level immediately adjacent to the bucketing and hopper overflow. The plumes are predicted to comprise fine silts and are expected to drift for some distance before settling (**Figure 7-21**).

Cumulative sedimentation patterns - Modelling of all dredging activities along the navigation channel, turning basin and berth pocket was undertaken for all seasons of the year as part of the Phase 1 modelling. The results of this cumulative modelling are presented in APASA (2006a); the modelling also accounted for nearshore trunkline installation activities occurring in parallel. Total monthly sedimentation patterns show a general trend of light deposition in association with trailer suction hopper dredging of the turning basin and berth pocket. Deposition rates are predicted to increase significantly when cutter suction dredging is undertaken in tandem with trailer suction hopper dredging in these same areas. As the dredging activities move along the navigation channel and gas trunkline, and away from the shoreline, deposition is predicted to remain elevated but localised, thus following the dredging footprint away from shore. Drilling and blasting in tandem with backhoe dredging nearshore is likewise predicted to result in limited deposition, local to Holden Point. When the trailer suction hopper dredge joins these activities near Holden Point to collect deposited material from the cutter suction dredge operations, deposition is predicted to increase. However, the plume associated with these combined activities is predicted to remain localised. Predicted impacts from sedimentation are discussed further in **Section 7.9.10.4**.

7.9.7.9 Dredge Spoil Disposal

The disposal of sediment from trailer suction hopper dredge vessels will result in an initial rapid descent of solids, with the heavy particles tending to entrain lighter particles. This is followed by a billowing of lighter components back into the water column after the sediments collide with the seabed (**Figure 7-22**). The behaviour of the discharged sediment plume will depend on a number of factors including prevailing currents at the time of discharge, discharge frequency, discharge volume and composition of discharged material (that is fine versus coarse material). A small proportion of the lighter sediments will also remain in suspension over longer time periods and may be trapped by density layers, if present. Simulations of spoil disposal operations focussed on the far field fate of particles due to transport and sinking after the initial dump phase. As a consequence, simulations were run with the initial vertical distribution specified to represent the 'post collision' phase for a case where a high proportion of the sediments are re-suspended after collision with the seabed (APASA 2006a).

As mentioned previously, the Phase 1 modelling originally modelled spoil disposal for all months of the dredging programme based on the assumption that the majority of spoil would be disposed into spoil ground A/B. Subsequent Phase 3 modelling was based on a modified spoil disposal plan for selected seasons (**Table 7-25**). Under the modified plan, only a relatively small amount of spoil requires disposed into spoil ground A/B and northern extension, with the majority being disposed into deep water spoil ground 2B.

Seasonal patterns of TSS and sedimentation concentrations for each month of disposal under varying environmental conditions during the year were established during the Phase 1 modelling. Only selected seasons of spoil disposal were modelled during Phase 3 based on the Phase 1 seasonal observations. Phase 3 results are indicative of TSS and sedimentation concentrations that can be expected during the two most distinct seasons: summer and winter. The model outputs from this phase are presented in this assessment.

Figure 7-19a Example of TSS levels Predicted from Trailer Suction Hopper Dredge Operating at the Berth Pocket Location under Variable Environmental Conditions – During Spring Tide Phase and East to South-East Winds

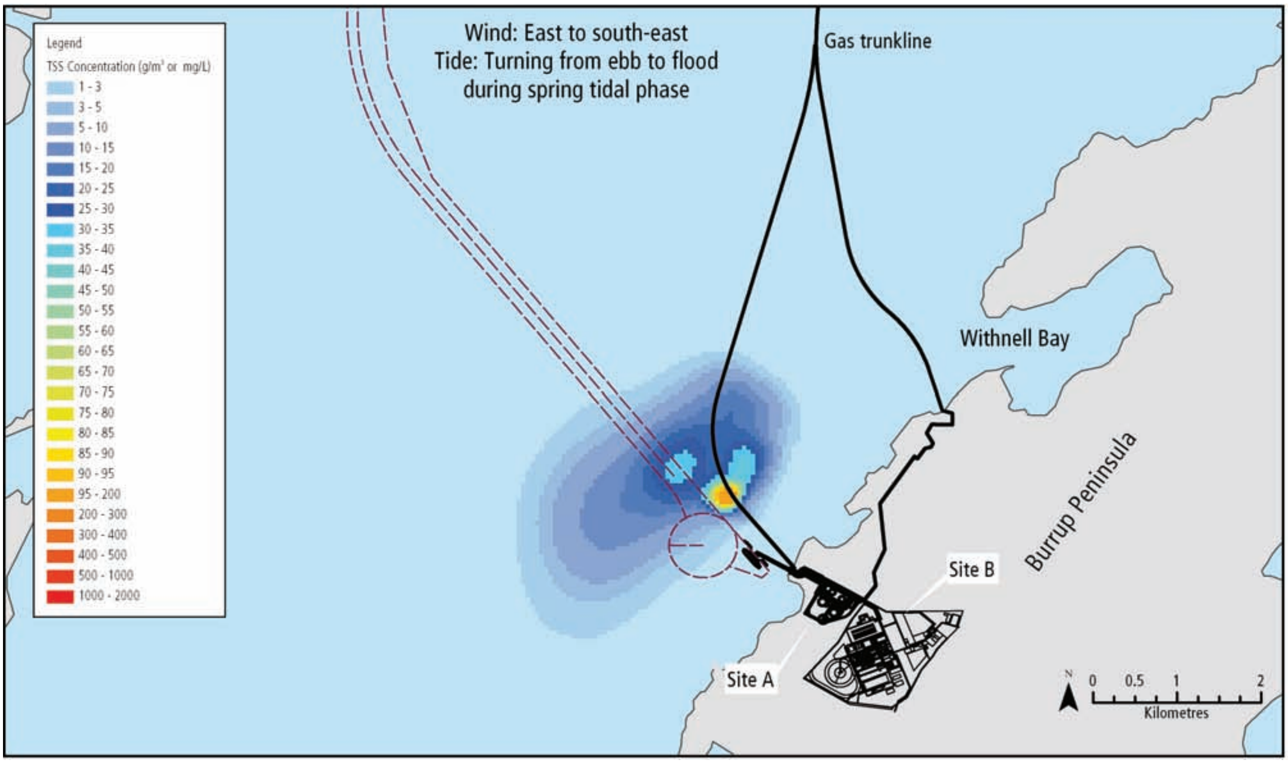


Figure 7-19b Example of TSS levels Predicted from Trailer Suction Hopper Dredge Operating at the Berth Pocket Location under Variable Environmental Conditions – During Neap Tide and Strong South West Winds

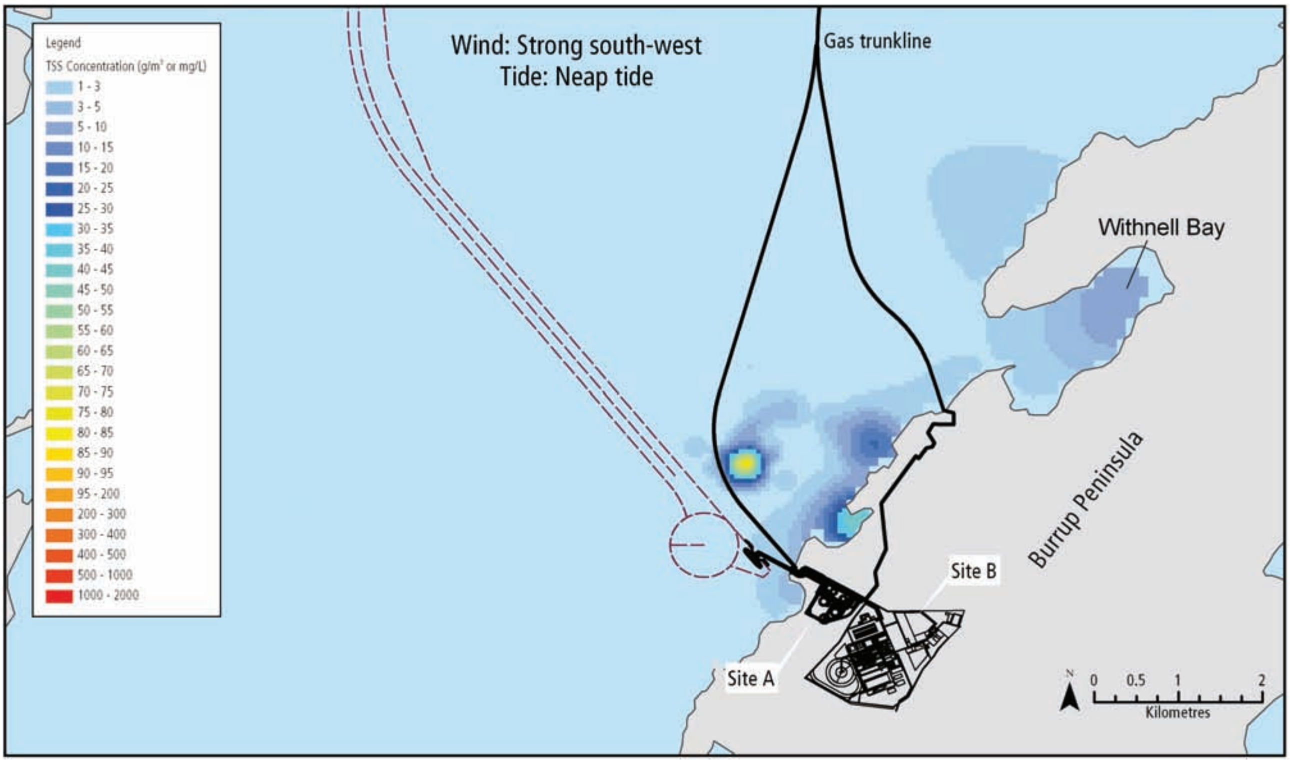


Figure 7-19c Example of TSS levels Predicted from Trailer Suction Hopper Dredge Operating at the Berth Pocket Location under Variable Environmental Conditions – During Spring tide and Strong South-East to South-West winds

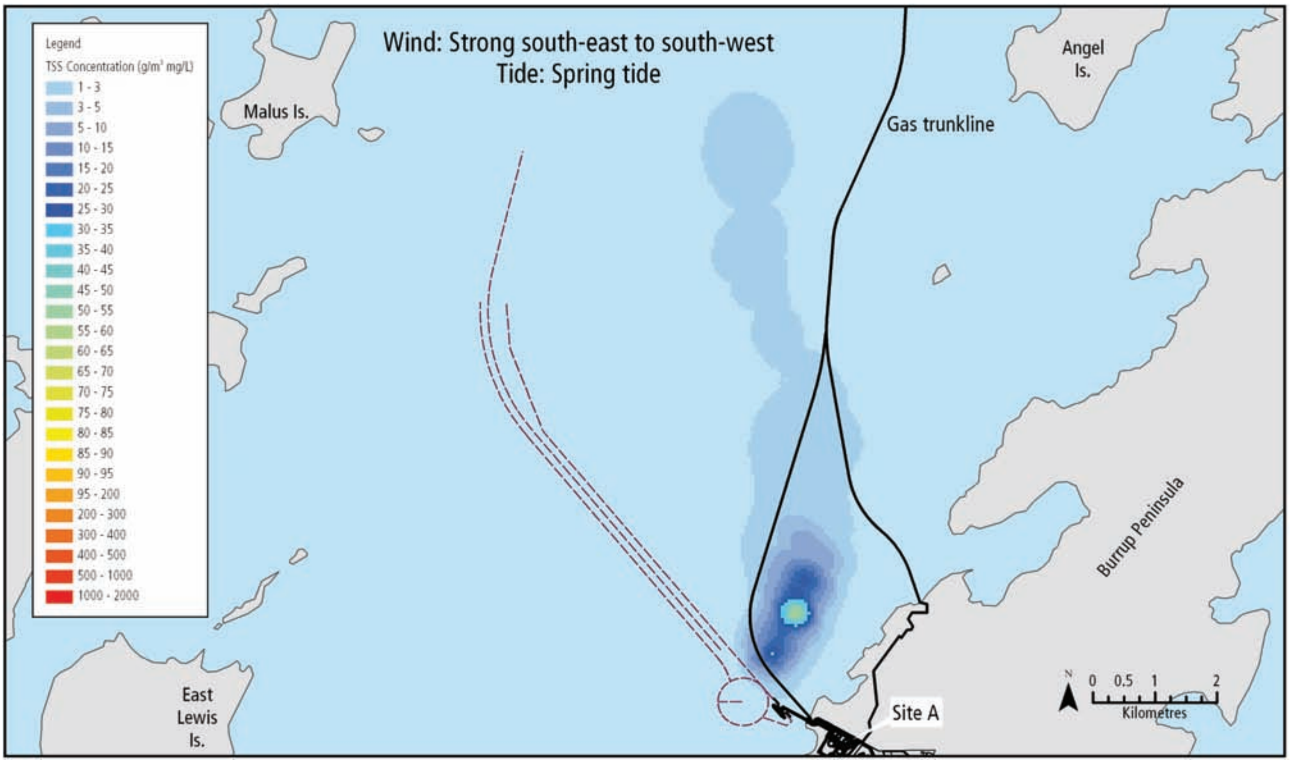


Figure 7-20a Example of Instantaneous TSS Concentration Predicted from Cutter Suction Dredge Operating at the Berth Pocket Location Under an Ebbing Spring Tide with Wind from the South-East

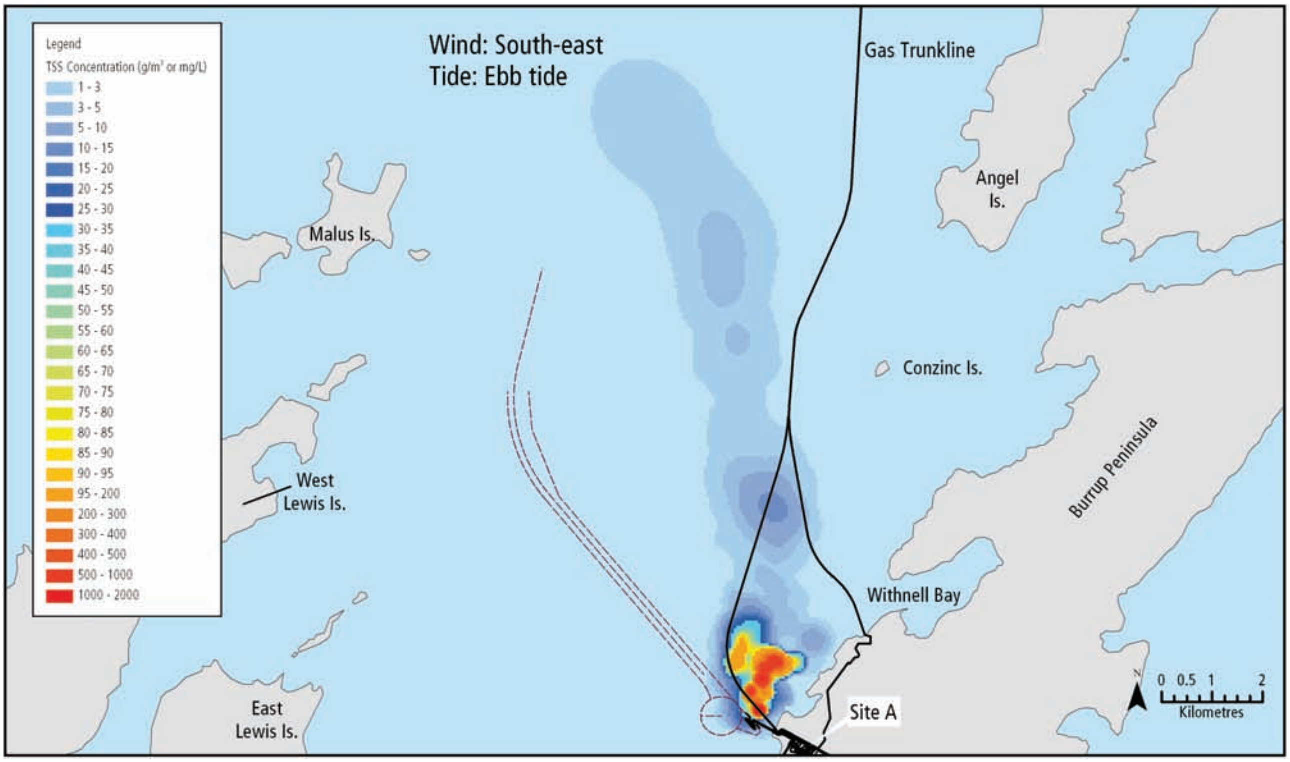


Figure 7-20b Example of Instantaneous TSS Concentration Predicted from Cutter Suction Dredge Operating at the Berth Pocket Location Under Ebbing Neap Tides and Wind from the South-West

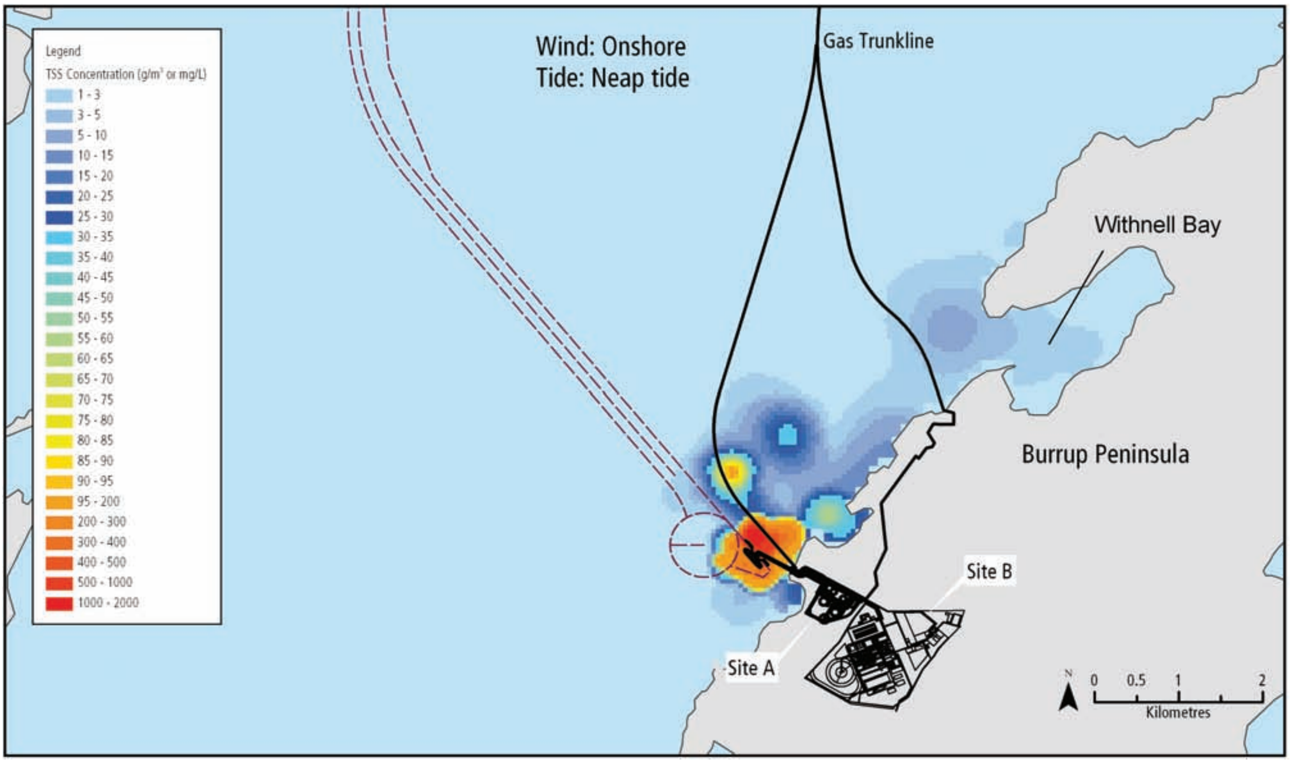


Figure 7-21 Example of Instantaneous TSS Concentration Predicted from Backhoe Dredge Operating at the Berth Pocket

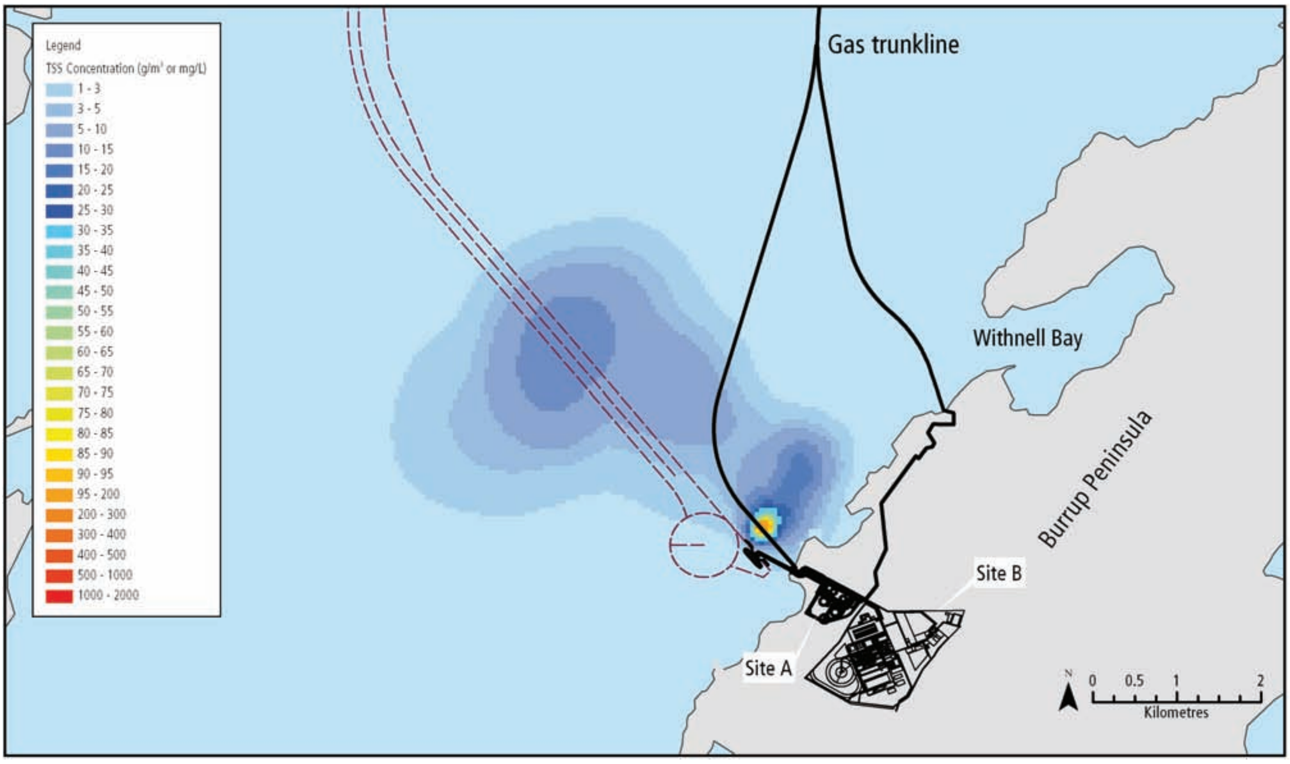
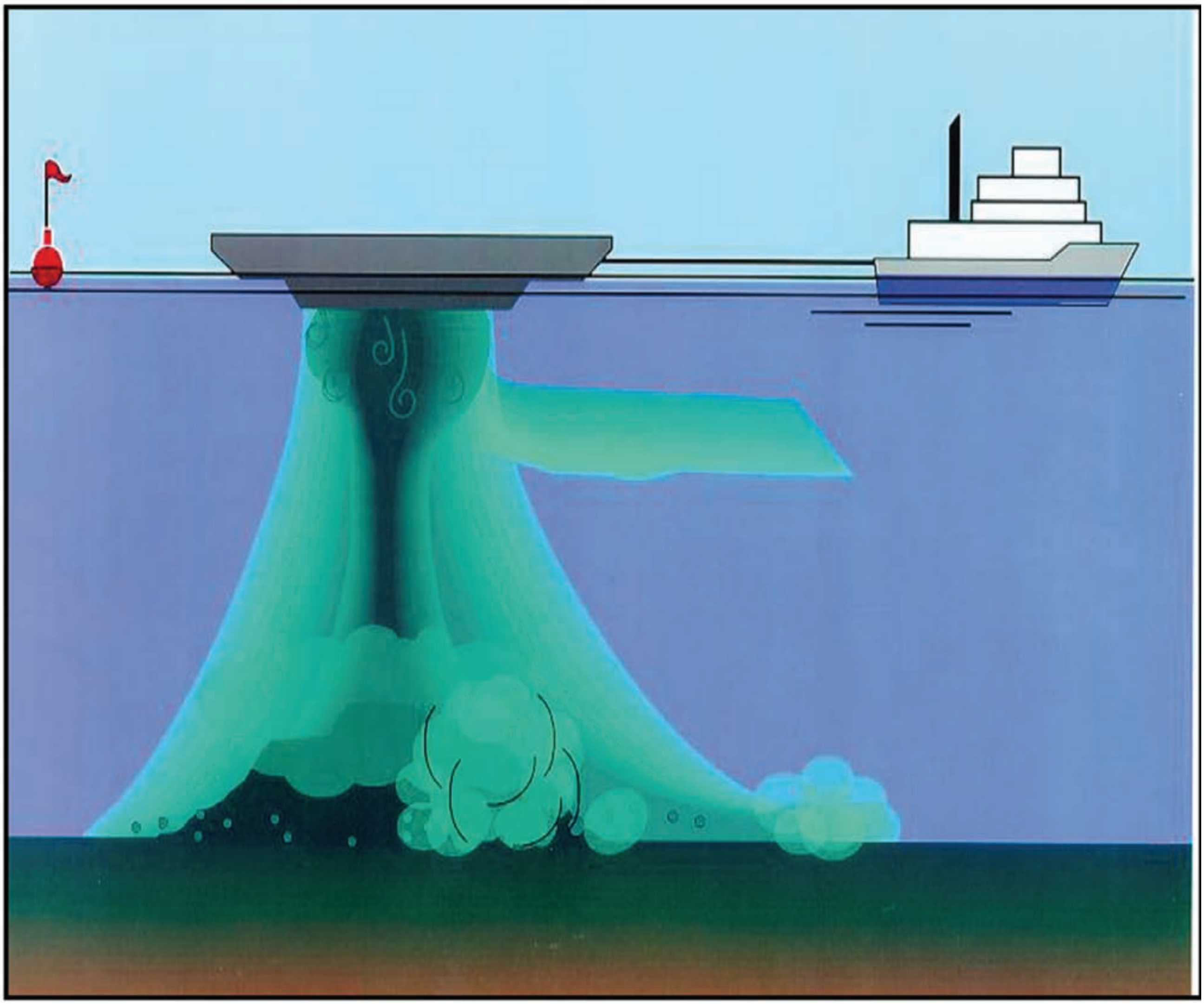


Figure 7-22 Typical Behaviour of Sediments Dumped from a Hopper Barge



Source: ASA 2004

The model outputs for spoil disposal simulations present the location of sensitive receptors where daily TSS concentrations for each 30 day period of disposal have been developed to provide an indication of the persistence of the plume over time. For the TSS plots, these locations are referred to as 'T1, 'T2' etc. The relationship between plume dispersion and TSS concentrations at specific receptors is discussed further in **Section 7.9.5**.

Modelling has also been undertaken to represent cumulative sedimentation from spoil disposal onto the seabed based on 24-hour operations over a 30 day period. Discharges were placed randomly within the defined disposal areas on the basis that disposal operations would aim to achieve an even deposition of spoil. Refer to **Figure 4-15** for defined disposal areas within spoil ground A/B, depicted schematically in the figures below.

Model results for sedimentation are presented and discussed in **Section 7.9.10.4**

Disposal of Fine Material into Mermaid Sound Spoil Ground A/B

The revised dredging programme assumes that a trailer suction hopper dredge will initially dredge the loose fine sediments from the surface of the turning basin and berth pocket and this material will be disposed into the northern portion of the existing spoil ground A/B during the winter wind regime. An example of the predicted maximum TSS concentrations at any depth from a sequence of 30 days disposal into this spoil ground during the winter wind regime is presented in **Figure 7-23**. The figure shows contour lines of equal TSS concentrations, that is, locations predicted to experience the same maximum TSS concentration at any depth at some time during the 30 day model period. Note that these peaks would be experienced at different times and the figure does not represent an instantaneous distribution of TSS concentrations.

Disposal operations are predicted to generate elevated TSS concentrations within the sinking plume. However, entrainment by heavy particles is expected to limit the suspension time for a proportion of the finer sediments. Given the relatively strong tidal currents running north-south and then diverting east-west around the southern end of Angel Island, simulations indicated that most deposition would be along these axes. Total suspended sediment concentrations at the subtidal reefs near Conzinc Island (site 'T2') and approximately 3 km to the south-east of the disposal site are predicted to experience TSS concentrations above background levels on only a few days of the 30 day period (**Figure 7-35a** and **Figure 7-35b**).

TSS concentrations at this location were predicted to peak at approximately 15 mg/l above background on any given day during this period. Cumulative sedimentation during 30 days of disposal into spoil ground A/B under winter conditions is given in **Figure 7-36**. Sedimentation patterns and effects are discussed further in **Section 7.9.10.4**.

Disposal of Coarse Material into a Northern Extension of Mermaid Sound Spoil Ground A/B

Simulation of sediment disposal into the western and northern margins of spoil ground A/B and a 300 m northerly extension of this ground during transitional and summer months indicated that most material would settle within 1–2 km of the disposal ground and onto sandy habitat, but lighter deposition could occur on surrounding reef habitat. Maximum TSS concentrations during 30 days of disposal during transitional weather patterns indicate dispersal of sediments, predominantly to the north and west, away from the spoil ground disposal location (**Figure 7-24**). Total suspended sediment concentrations close to Conzinc Island (Site 'T5') and to the south-east of the disposal site are predicted to be low with pulse concentrations greater than 100 mg/l above background on occasion (**Figure 7-35a** and **Figure 7-35b**). **Figure 7-24** indicates that suspended sediments are predicted to reach the subtidal reefs south of Malus Island. TSS concentrations at site 'T3' (south of Malus Island) are predicted to exceed background levels on only a few days of the month (**Figure 7-35a** and **Figure 7-35b**). Peak concentrations at this location are predicted to be approximately 15 mg/l above background.

Sedimentation rates predicted for 30 days disposal in transitional months indicate a fairly wide dispersal of sediments on the seabed compared to disposal of fine sediments into spoil ground A/B in winter months. This result appears counter-intuitive in that it is expected that coarser materials would be less mobile and may be due to a range of factors including:

- Area CDG within spoil ground A/B (refer to **Section 4**, **Figure 4-15**) is smaller and close to Angel Island and therefore more strongly affected by currents migrating around this island. Area ABFEIH within spoil ground A/B (refer to **Section 4**, **Figure 4-15**) by comparison, experiences a wider range of current directions.
- Area CDG is constrained to shallower water. The western edge of Area ABFEIH has a depth of 18–19 m compared to 10–12 m over Area CDG.

Cumulative sediment concentrations are predicted to peak at 20 mg/cm^2 at the subtidal reefs to the west of Angel Island (location 'S3') during the 30 days of transitional conditions modelled (**Figure 7-41**). Sedimentation during summer months is predicted to occur as far west as Malus Island and West Lewis Island (location 'S2') (**Figure 7-41**).

Disposal of spoil into the same location but during summer months indicates a north-south dispersal of sediments within Mermaid Sound (**Figure 7-25**). Fine material is predicted to reach the subtidal reefs to the west of Angel Island where TSS concentrations at 125 mg/l may occur at a rate of one day within the month (**Figure 7-35b**). The sediment plume is not predicted to reach the subtidal reefs at East Intercourse Island or Malus Island. Example cumulative sedimentation concentrations for 30 days disposal during summer months predicted that concentrations up to 50 mg/cm^2 may be reached at the subtidal reefs on the slopes of Angel Island (**Figure 7-41**).

Disposal into Deep Water Spoil Ground 2B

Simulations of trailer suction hopper dredge disposal operations into the proposed deep water spoil ground 2B have been undertaken for a representative 30 day period for each of summer and winter conditions. During the summer conditions it is predicted that sediments will be dispersed along a north-east to south-west axis (**Figure 7-26**). TSS concentrations at the subtidal shoal to the north-east of Rosemary Island ('T8') during this period were predicted to experience elevated levels of up to 50 mg/l for short periods on two of the 30 modelled days. On a further eight occasions TSS concentrations were predicted to exceed background levels by up to 10 mg/l (**Figure 7-35a** and **Figure 7-35b**). On all other modelled days of the month, no TSS concentrations above background at location 'T8' were predicted to occur. Cumulative sedimentation concentrations (30 days disposal) are predicted to peak at approximately 5 mg/cm^2 (above background) at site 'S5' on the subtidal shoal to the north-east of Rosemary Island with above background sedimentation predicted only on a few days of the month.

Disposal operations in winter months are likely to be influenced by prevailing winds from the east and south-east, resulting in the sediment pile skewing to the west of deep water spoil ground 2B (refer to **Figure 7-27**). None of the subtidal reefs within the outer islands of the Dampier Archipelago are predicted to receive (above background) TSS or sedimentation concentrations under these conditions.

Figure 7-23 Example of TSS Concentrations for a Sequence of Disposal Operations into Spoil Ground A/B over 30 days Comprising Fine Material During Winter. The plot shows the highest TSS concentration at any time at any depth during the 30 days of Spoil Disposal.

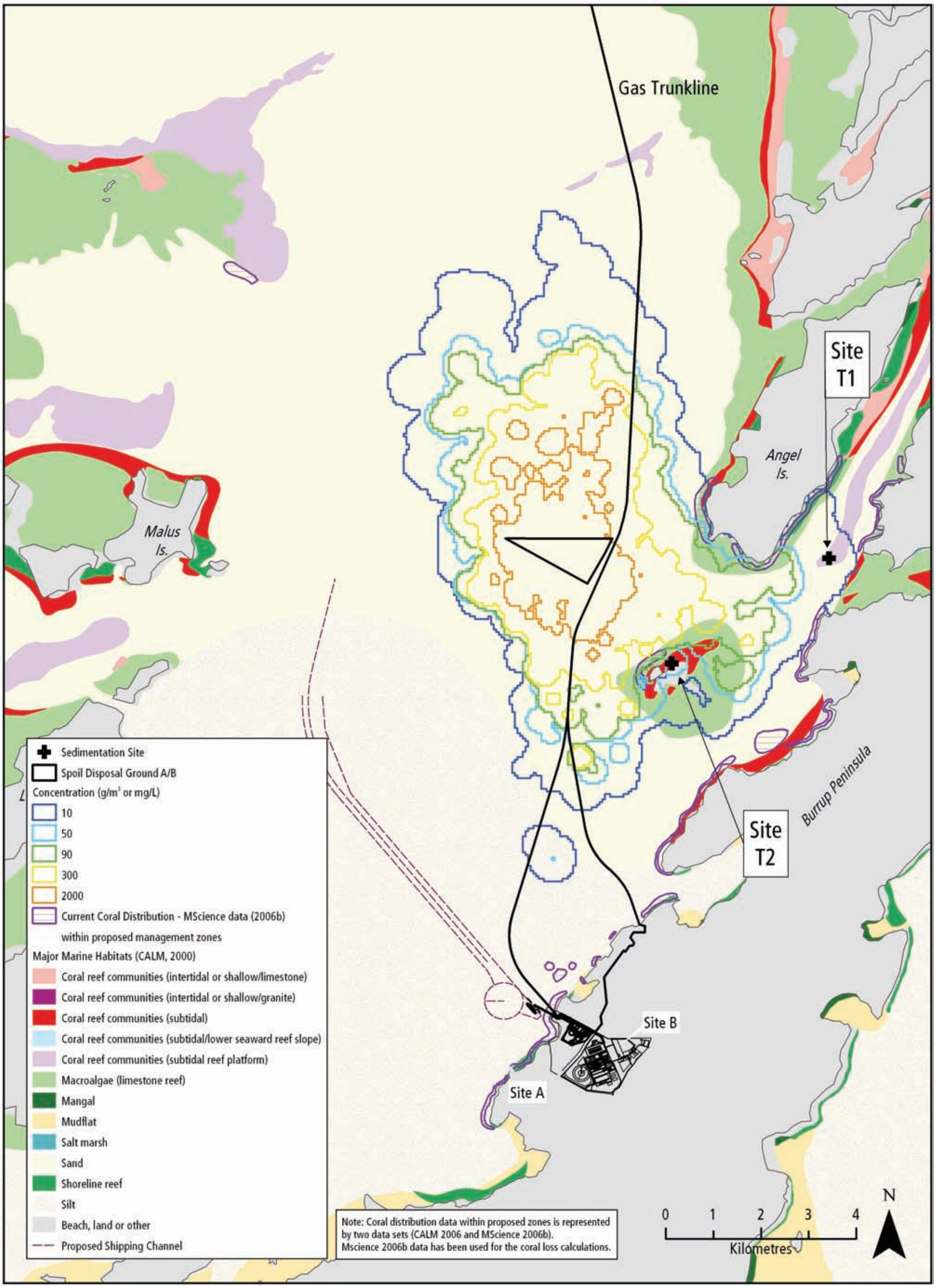


Figure 7-24 Example of TSS Concentrations for a Sequence of Disposal Operations into a Northern Extension of Spoil Ground A/B over 30 days Comprising Coarse Material During Transitional Period. The plot shows the highest TSS concentration at any time at any depth during the 30 days of Spoil Disposal

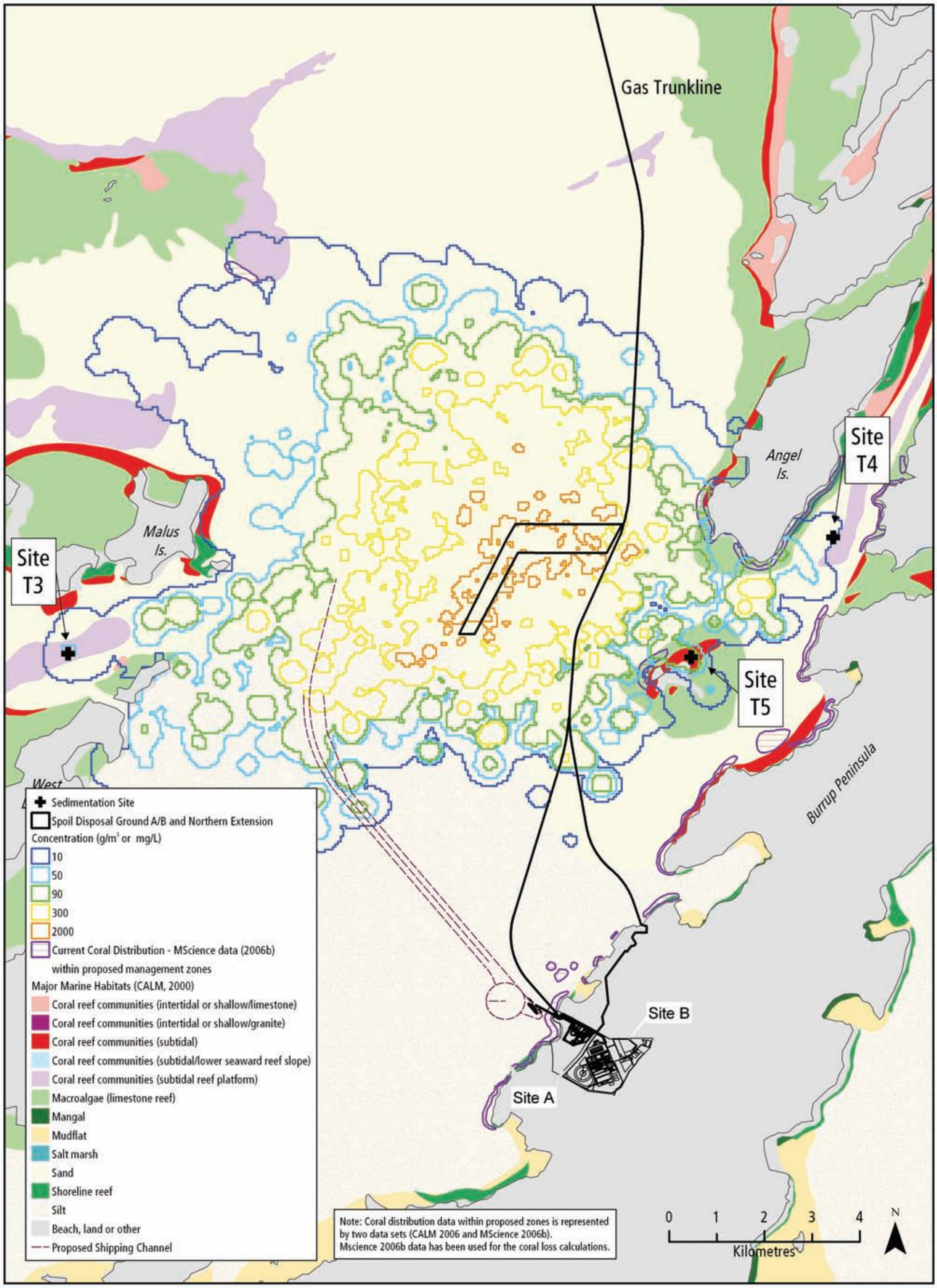


Figure 7-25 Example of TSS Concentrations for a Sequence of Disposal Operations into a Northern Extension of Spoil Ground A/B over 30 days Comprising Coarse Material During Summer. The plot shows the highest TSS concentration at any time at any depth during the 30 days of Spoil Disposal

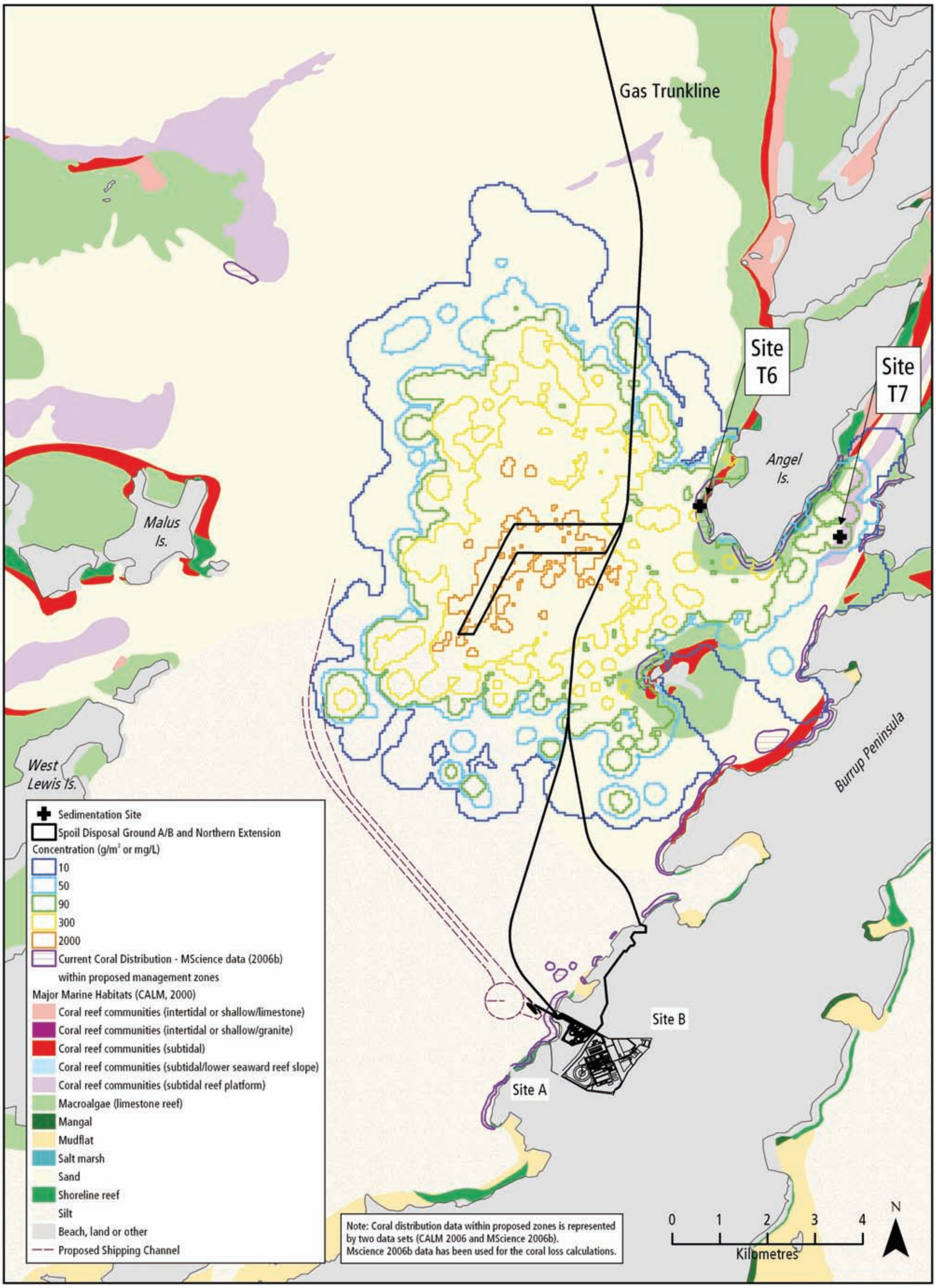


Figure 7-26 Example of TSS Concentrations for a Sequence of Disposal Operations into Deep Water Site 2B over 30 days in Summer Months. The plot shows the highest TSS concentration at any time at any depth during the 30 days of Spoil Disposal

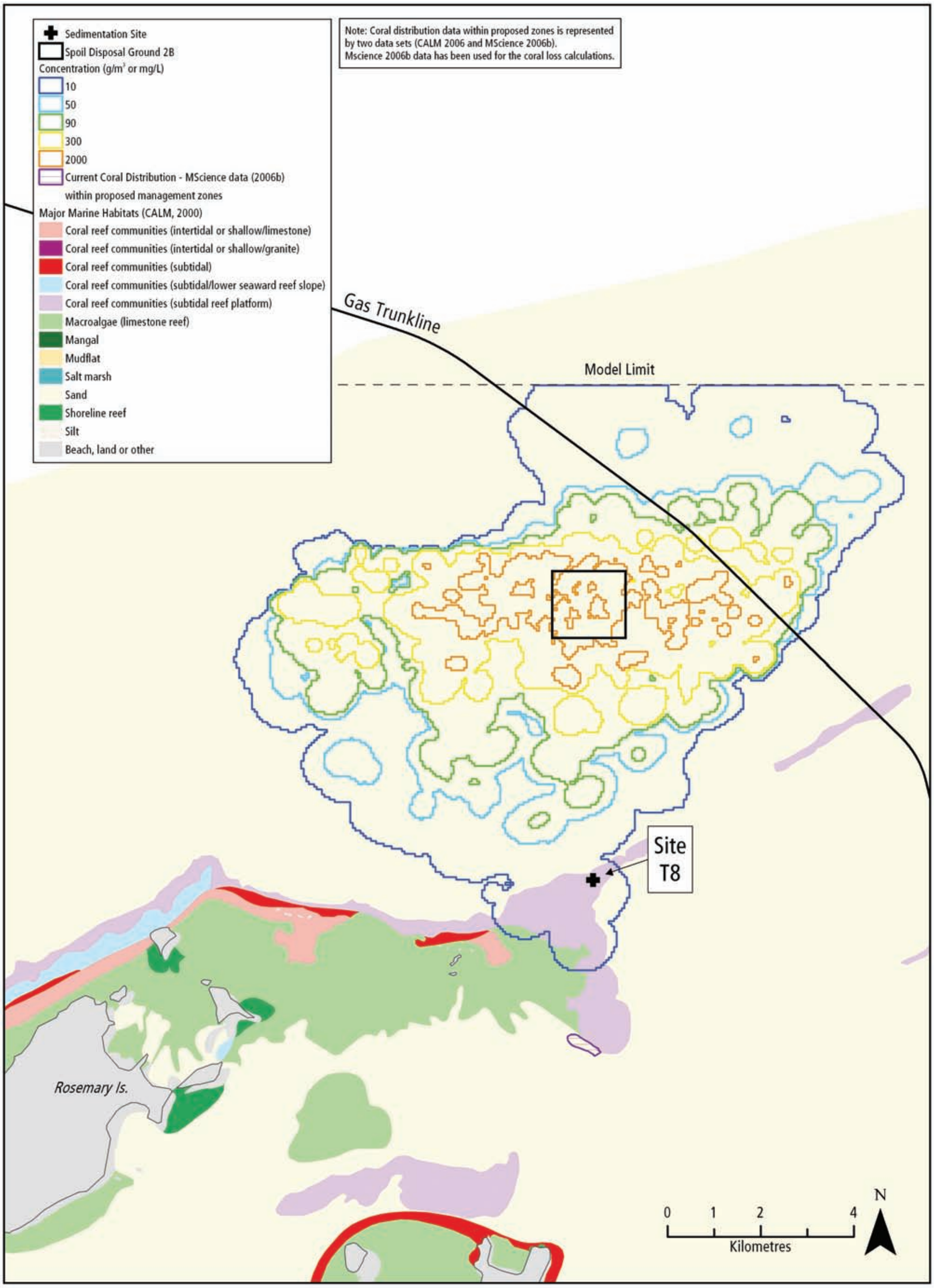
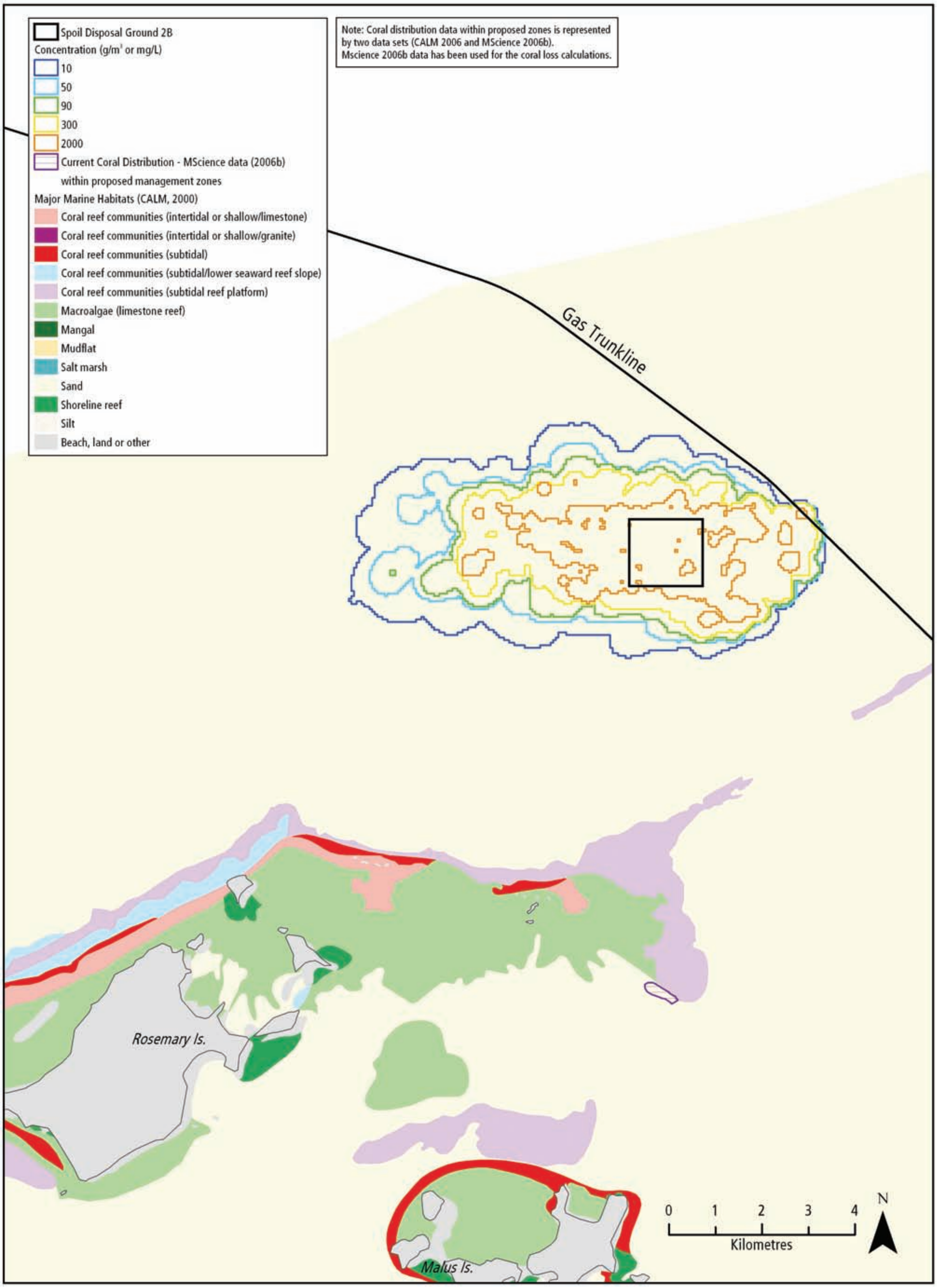


Figure 7-27 Example of TSS Concentrations for a Sequence of Disposal Operations into Deep Water Site 2B over 30 days in Winter Months. The plot shows the highest TSS concentration at any time at any depth during the 30 days of Spoil Disposal



7.9.7.10 Dredging Along Sections of the Gas Trunkline

Trenching along the offshore gas trunkline, in water depths of 20–50 m, will involve trailer suction hopper dredge trenching with side-casting of sediment back to the seabed at a distance of 1–2 km. Simulations were carried out using the expected production rates and sediment grain sizes for the gas trunkline route. The simulations assumed that sediments would be discharged vertically at approximately 8 m below sea level.

Simulations of discharge at the entrance to Mermaid Sound indicate that the suspended sediment plume would circle with the tide and extend for 1–2 km within the lower water column. Relatively low TSS concentrations (5–10 mg/l) are at times predicted to pass over Hamersley Shoal and the submerged reef to the west of the entrance to Mermaid Sound, but exposure is expected to be short-lived as the plume windmills with the tide. **Figure 7-28** provides two examples of the predicted plume distribution at instantaneous points in time from a 30-day simulation showing the windmilling of the plume with the tide and the concentrations of sediments in the lower water column. In the upper image the tide is turning from ebb to flood. In the lower image, the tide is flooding.

Simulation of sedimentation resulting from trunkline trenching at the same location indicates that loads of greater than 5 mg/cm^2/month are likely to be constrained to areas of sand habitat, with the possible exception of the small submerged reef to the west of the entrance to Mermaid Sound (south-west of Legendre Island) (**Figure 7-29**).

Nearshore (0 to 20m), trenching to bury the gas trunkline will be carried out by a backhoe dredge from the intertidal zones out to depths where a trailer suction hopper dredge can be used. A cutter suction dredge may also be used in localised areas of hard seabed. The dredge will side cast material (similar to the method used for the shipping channel and turning basin) which will be picked up by a trailer hopper barge. Predictions of TSS concentrations and sedimentation rates along the nearshore sections of the gas trunkline were based on modelling undertaken for a trunkline crossing at Holden Point beach (APASA 2006a). Simulations indicate that backhoe dredge operations are likely to generate locally elevated TSS concentrations (60–90 mg/l) around the dredging area. The shallow waters are likely to reduce dilution rates of the fine material which will be re-suspended from this operation.

The predicted plume, under light wind conditions from the south-east and an ebbing tide, is expected to extend approximately 3 km from the coast. At other times, the plume is expected to be contained close to the coastline. The suspended sediments are expected to primarily consist of fine silts and clays. These sediments are predicted to disperse widely, hence cumulative sedimentation above 5 mg/cm^2 over one month is predicted to occur over a very localised area. Though the current trunkline shore crossing is situated slightly north of the modelled location, results are indicative of the likely plume behaviour and associated sedimentation rates. Sediment deposition rates are predicted to be low. The area of potential impact from the trunkline crossing is likely to be located within the zone of effect generated by dredging of the turning basin and berth pocket. Sediment plumes and the extent of sedimentation associated with nearshore dredging for the trunkline are therefore considered unlikely to extend further than those associated with dredging of the navigation channel, turning basin and berth pocket.

Cumulative sedimentation from installation of the gas trunkline nearshore, coinciding with dredging of the navigation channel, turning basin and berth pocket are discussed in **Section 7.9.7.8**.

Figure 7-28 Examples of the TSS Concentrations Predicted from Side-Casting of Trailer Suction Hopper Dredge Production along the Trunkline Trench at the Entrance to Mermaid Sound.

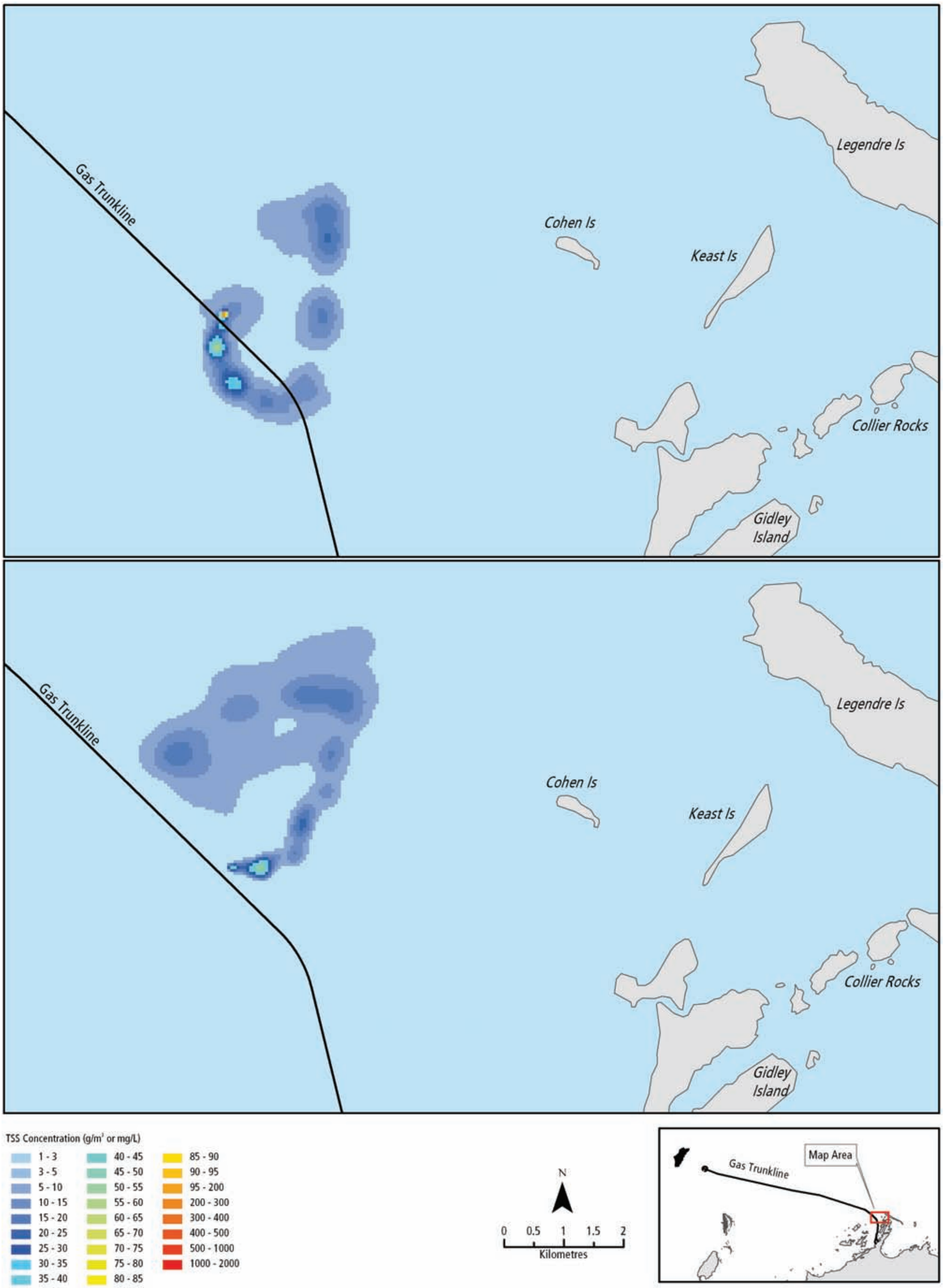
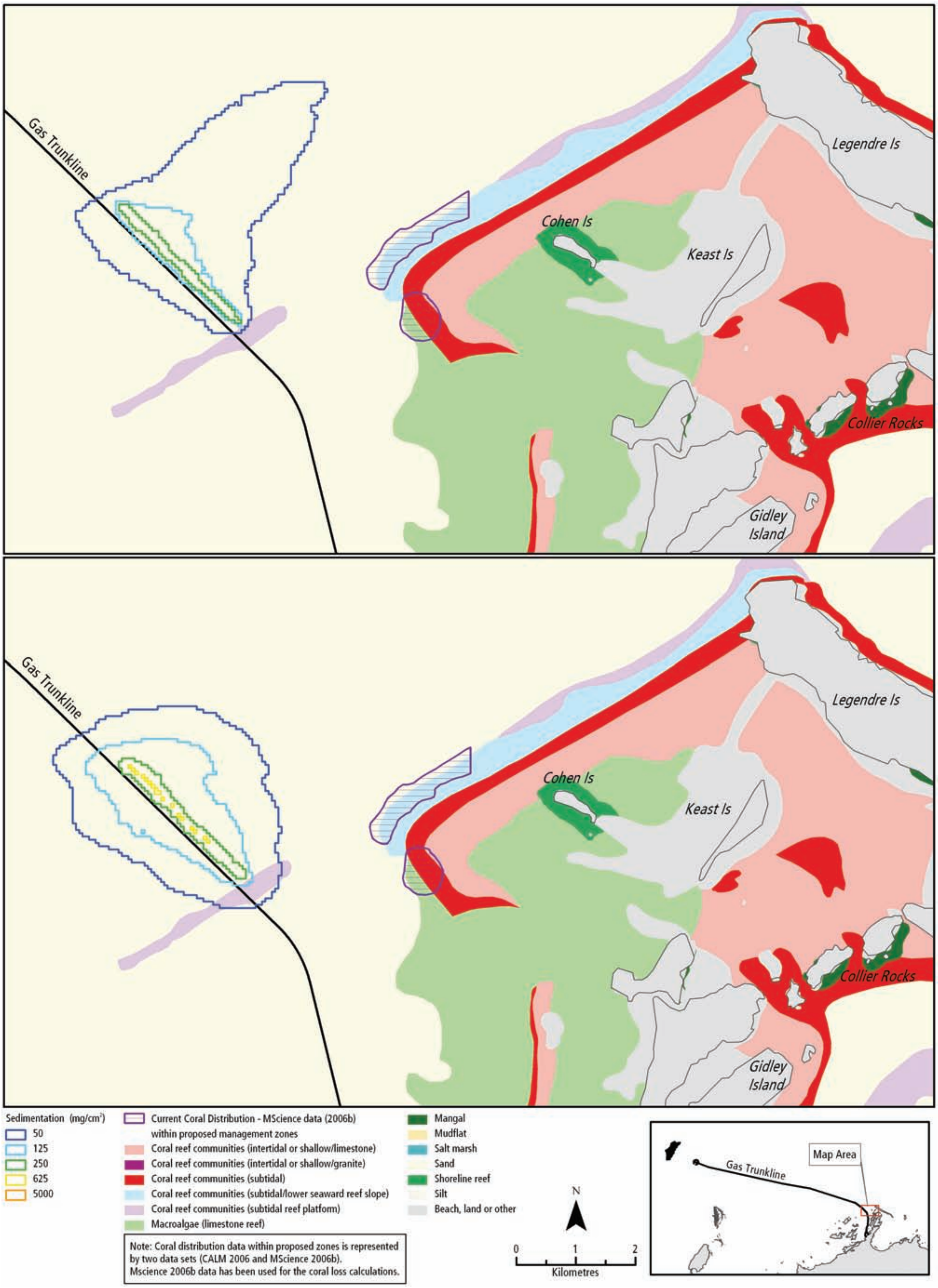


Figure 7-29 Cumulative Sedimentation Predicted from One Months Discharge from Trailer Suction Hopper Dredge Trenching along the Trunkline Route to Holden Point. Results are from Discharge Commencing at the Inshore End (20 m Depth Contour) and Progressing Offshore. Upper image is for discharge during example summer conditions. Lower image is for discharge during example winter conditions.



7.9.8 Effects on Biota Excluding Benthic Primary Producers

Effects on biota from dredging are caused by increased suspended solids in the water column, both from dredging and associated spoil disposal activities. Suspended solids can cause light attenuation, abrasion, clogging of pores, respiratory and feeding organs, and smothering of benthic biota. Toxins released from contaminated sediments during dredging and ocean disposal can likewise have detrimental impacts on the marine ecosystem. Potential effects on biota caused by the Pluto LNG Development dredging activities are discussed in the following section, with direct impacts discussed separately in **Section 7.5**. Impacts on benthic primary producers are discussed in **Section 7.9.9**.

7.9.8.1 Suspended Solids

Plankton – Waters in the Dampier Archipelago are considered oligotrophic and phytoplankton are generally present in low densities for much of the year, except perhaps on occasions during spring/summer when plankton blooms contribute locally to turbidity (Pearce et al. 2003).

A decrease in light penetration due to suspended solids can cause a decrease in phytoplankton productivity and standing stock; however, phytoplankton has the potential to develop light-shade adaptations and react quickly to favourable light conditions. Rapid tidal movements, storms and cyclones naturally cause large changes in water clarity over short time periods in the Dampier Archipelago. High spatial and seasonal variability in nutrient and chlorophyll-*a* concentrations throughout the Dampier Archipelago have been recorded (Pearce et al. 2003), and suggest a highly variable occurrence of phytoplankton. High levels of suspended solids from dredging activities are predicted to be short-lived rather than causing a build-up over time and are expected to add to an already patchy pattern of natural variation in turbidity. The impacts on phytoplankton in the Dampier Archipelago and in the vicinity of the deep water spoil grounds (2B and 5A) are therefore considered slight and are likely to be localised and short-lived.

Zooplankton – Zooplankton rely on phytoplankton as a food source and can potentially suffer from a decline in grazing opportunities, with potential knock-on effects up through the food web. Zooplankton may also suffer from clogged feeding mechanisms as a result of elevated suspended solids, particularly very fine particles, in the water column. Given that potential impacts from increased TSS on phytoplankton are likely to be slight, impacts on zooplankton are considered insignificant.

Sponges and Soft Corals – Sponge communities with a high diversity of sponges, soft corals and other coelenterate species are found in various locations within the Dampier Archipelago as described in **Section 6.3.3**. Some species of sponge and soft corals have symbiotic relationships with cyanobacteria and phytoplankton, and therefore require light for photosynthesis (Michalek-Wagner and Willis 2001). Persistent shading caused by turbidity can result in the inability of these organisms to photosynthesise and can result in adverse effects including bleaching and mortality (Roberts et al. 2006; Michalek-Wagner and Willis 2001). Other species of sponges and soft corals are entirely heterotrophic and are therefore not affected by limited light.

Little is known about tolerance levels of sponges and soft corals to turbidity. A study by Rogers (1979), attempting to simulate shading caused by turbidity, demonstrated that gorgonians displayed no signs of bleaching when shaded for five weeks. Suspended solids may also cause abrasion and damage to the surface of sponges and soft corals, but the impacts are not well understood.

During spoil disposal at spoil ground A/B and the proposed northern extension of A/B, the communities at the entrance to Mermaid Sound, north and south of Malus Island and at the south–west end of Flying Foam Passage are predicted to experience generally low concentrations of suspended solids. Indicative modelling suggests that these communities may be exposed to periodic pulses of elevated TSS concentrations up to approximately 50 mg/l (**Figure 7-24** and **Figure 7-25**). These pulses are not predicted to persist over time (APASA 2006a) and are unlikely to result in shading induced impacts on sponges or soft corals.

Modelling furthermore indicates that, during summer, spoil disposal at spoil ground 2B may result in periodic pulses of elevated suspended solids (up to 50 mg/l) to the west of the entrance to Mermaid Sound where Bancroft and Sheridan (2000) have indicated the existence of a sponge and soft coral community (**Figure 7-26**). These elevated concentrations are not predicted to build up and persist over time but return to previous levels within hours or days (APASA 2006a). No significant effects from turbidity induced shading are therefore expected. Persistence of plumes associated with both dredging and spoil disposal is discussed in **Section 7.9.10.4**.

Dredging associated with gas trunkline installation through Mermaid Sound may result in elevated TSS levels over the sponge communities on the east side of the entrance to Mermaid Sound; however, concentrations are predicted to be relatively low (5–10 mg/l) and exposure short-lived (**Section 7.9.7.10**). Impacts on sponges resulting from gas trunkline dredging are therefore considered unlikely.

Fishes – The fish fauna of the outer islands of the Dampier Archipelago are dominated by coral reef fishes, while mangrove and silty bottom dwellers comprise the majority of the fish assemblages in the inner areas of the Archipelago, close to shore (**Section 6.3.4**).

Fish exposed to high suspended solid concentrations may suffer clogging and abrasive damage to gills and other respiratory surfaces. Resilience to suspended sediments is highly species-specific. A study by Nightingale and Simenstad (2001) showed concentration of several hundred mg/l caused lethal effects in 24 hours in some species, whilst other species sustained concentrations above 10 000 mg/l for seven days without effect. Suspended solid concentrations of over 40 000 mg/l have been associated with gill damage in coho salmon (*Oncorhynchus kisutch*), with concentrations of 100 000 mg/l resulting in mortality (Lake and Hinch 1999).

Reduced oxygen levels, associated with elevated TSS concentrations, have been shown to result in increased metabolic rate and a reduction in the ability of fish to cough, maintain ventilation rates and clear gills clogged with sediment. Such cumulative stressors are thought to be likely contributors to mortality during extended durations of exposure to high levels of suspended sediment (Servizi and Martens 1991).

Reduced light due to turbidity may also affect fish behaviour. Light conditions determine the ability of fish to school, signal the presence of potential predators, set a background against which feeding relationships develop and provide migration orientation.

Some fish are likely to avoid areas of high suspended solids, whilst fish within the inner Dampier Archipelago are likely to be adapted to naturally large fluctuations in turbidity as well as periodic extreme turbidity events associated with storms and cyclones.

Throughout most of the effected areas, particularly the outer reef areas that support the most diverse fish populations, elevated TSS levels are not predicted to persist over time but rather return to background levels within hours or days (**Section 7.9.10.4**). These predictions are consistent with observations during previous dredging programmes in Mermaid Sound (Stoddart and Anstee 2005; LDM 1995; LSC 1986; LSC 1987; LSC 1989a). The outer reef north-east of Rosemary Island, the reef habitat closest to spoil disposal ground 2B, is predicted to experience generally low levels of suspended solids, with occasional peaks returning to background levels within hours or days (**Figure 7-35a** and **Figure 7-35b**). Impacts from elevated suspended solids on fish are therefore likely to be slight.

Marine Mammals and Reptiles – Dolphins, dugongs, sea turtles and sea snakes in the area are unlikely to be adversely affected by increased levels of turbidity. These animals may exhibit behavioural and avoidance responses to areas of elevated turbidity. While no information regarding direct impacts of increased turbidity on marine mammals or reptiles was found, there is potential for indirect impacts by way of displacement of prey species such as fish that may avoid areas of high turbidity. It is unlikely however, that marine mammals or reptiles will be affected in this way given the low risk of impacts on such prey species. Site fidelity is not considered to be strong in cetaceans generally, and it is assumed that the animals would move to another, unaffected area to feed.

A well documented impact from dredging on turtles and dugongs is the disturbance to important habitats such as seagrass meadows from direct removal during dredging or increased sedimentation associated with dredging and spoil disposal. There are no seagrass meadows in the dredging footprint itself, and the general presence of seagrass habitat within Dampier Archipelago is relatively sparse (**Section 7.9.9.2**). High occurrences of dugongs and turtles have been observed on the seaward side of Hamersley Shoal at the entrance to Mermaid Sound (J Stoddart [MScience] 2006 pers comm. May 2006), approximately 8 km east of the offshore spoil ground 2B, and 10 km north of the spoil ground A/B and the proposed northern extension (**Figure 7-10**). There is no data available to confirm the presence of dense seagrass meadows in this area, and it is possible that the animals use the area for other purposes than feeding. No direct disturbance of the seabed will take place in this area, and it is considered unlikely that increased sedimentation from spoil disposal at offshore spoil ground 2B will have an impact on the habitat around Hamersley Shoal.

Impacts on benthic primary producers including seagrass are discussed in detail in **Section 7.9.9**. Impacts to EPBC Act listed species are discussed in **Section 7.9.13**.

Other Invertebrates

Elevated levels of suspended solids can affect feeding and growth of suspension feeders. For example, bivalves deal with re-suspended particulates by reducing pumping rates and rejecting inorganic particles. When suspended sediment concentrations rise above a threshold at which bivalves can no longer effectively filter material, a dilution of the available algal food occurs (Nightingale and Simenstad 2001). As high levels of suspended solids are predicted to occur in pulses, exposed filter feeding invertebrates may suffer food deprivation periodically. The impacts associated with this periodic and localised disturbance are expected to be low.

7.9.8.2 Sedimentation

Many organisms have physiological or behavioural methods of dealing with sediments that settle on or around them, ranging from avoidance (such as fish, marine mammals and sea turtles) to tolerance and clearing of clogged pores (such as filter feeders). However, above certain thresholds, perturbations in sedimentation rates may adversely affect organisms, thus resulting in mortality, and consequently changes in abundance and distribution. Impacts on biota from dredging related sedimentation is discussed in this section, whilst impacts due to spoil disposal at the disposal site are discussed in **Section 7.5**.

Sponges and Soft Corals - Sponges are filter feeders and require free movement of water through their pores. Suspended solids can clog these pores and eventually lead to tissue necrosis and mortality. Little is known about the tolerance levels of sponges to sedimentation but it is evident that it varies between species (Burns and Bingham 2002a) and that it may influence species distribution (Bell and Barnes 2000a; Carney et al. 1999). Alterations in sedimentation patterns over a longer period may therefore lead to changes in community composition (Bell and Barnes 2000b).

It is believed that sponge morphology influences tolerance levels with smooth, vertical surfaces tending to collect less sediment than vase-shapes and level, rough surfaces. There is also evidence that sponges can clear themselves of smothering (Burns and Bingham 2000a; Riegl 1995) though the exact mechanism is unknown.

Soft corals are believed to better withstand siltation than hard corals, as their soft bodies are relieved of sediment as they sway with wave action (Sorokin 1995). However, active sediment rejection rates for soft corals have been shown to be lower than for hard corals with inflation of tissue the only active means observed (Riegl 1995). Although very little research has been undertaken on tolerance levels, it is understood that smothering and inundation can have detrimental effects (Riegl 1995).

Modelling of spoil disposal at spoil ground A/B and the northern extension indicates that the areas of sponge communities on the east side of the entrance to Mermaid Sound (south-west of Legendre Island) are unlikely to experience elevated levels of sedimentation above 5 mg/cm^2/month (**Figure 7-36** to **Figure 7-38**). Modelling of expected hard coral losses at the outer shoals of Mermaid Sound indicates the sponge communities will not be impacted assuming similar resilience between these coelenterates. Potential impacts on hard corals is discussed in detail in **Section 7.9.10**.

Benthic habitat mapping by Bancroft and Sheridan (2000) indicates the existence of sponge communities north of Malus Island and in Flying Foam Passage. Modelling indicates that these communities may experience localised patches of elevated sedimentation above 5 mg/cm^2/month during spoil disposal at the northern extension of spoil ground A/B during summer months (**Figure 7-38**). However, currents are strong through Flying Foam Passage and suspended particles are likely to resuspend and be transported out of the area. In situ observations suggest that suspended sediments naturally occurring in the passage originate from areas outside the inner harbour, where strong currents carry solids rich in calcium carbonate down through the passage and out of the inner harbour on outgoing tides (J Stoddart [MScience] 2006 pers comm. May).

Modelling of spoil disposal at spoil ground 2B indicates that the areas of sponge communities to the west of the entrance of Mermaid Sound (south-west of Legendre Island) are unlikely to experience elevated levels of sedimentation above 5 mg/cm^2 during winter wind regimes (**Figure 7-40**). However, these areas may experience localised elevations between 5 and 125 mg/cm^2/month during the summer regime (**Figure 7-39**).

Dredging and spoil disposal activities are not predicted to elevate sedimentation levels in the area of sponge communities on the seaward side of Hamersley Shoal at the entrance to Mermaid Sound, therefore no impacts are predicted.

Modelling of cumulative sedimentation during trenching and side casting activities associated with trunkline installation within Mermaid Sound predicts that sedimentation impacts on sponge communities are unlikely. The sponge communities inhabiting the submerged reef to the west of the entrance to Mermaid Sound (south-west of Legendre Island) are likely to experience elevated sedimentation rates up to 5 mg/cm^2/month (**Section 7.9.7.10**) however such levels are unlikely to cause an impact.

Given the low predicted rates of sedimentation for all areas of sponge communities throughout the Dampier Archipelago, and conservatively assuming a similar tolerance as scleractinian coral, no significant negative impact to sponges or soft corals are expected. Measures to limit the impact on sponge communities are discussed in **Section 7.9.15**.

Other Invertebrates - Sedimentation can impact all sessile biota by smothering and complete burial causing reduced feeding ability, suffocation and death. Sub-lethal effects mainly derive from reduced feeding ability, with growth retardation and reduced reproductive output as a consequence.

Whilst the marine environment in Mermaid Sound will be impacted upon by the proposed dredging operation, a large proportion of the impacted areas consist mostly of sandy and muddy areas. These areas are expected to recover rapidly following the completion of dredging.

7.9.8.3 Contaminants

During dredging and spoil disposal, common contaminants re-suspended by dredging in ports and harbours include hydrocarbons, heavy metals and anti-foulants, including TBT.

Tolerance levels to these substances vary between species and can alter community structure and ecosystem stability through species specific toxicity. Set values in the NODGDM (EA 2002) reflect the general tolerance level of the marine environment and determine whether spoil is suited for safe ocean disposal.

Both the upper and lower seabed wihtin the dredging footprint has been shown to contain potential relevant contaminants below screening levels defined within the NODGDM and is therefore considered suitable for ocean disposal. Dredging related toxic risks to the surrounding marine environment are therefore considered low.

7.9.9 Effects on Benthic Primary Producers in Dampier Archipelago

7.9.9.1 Benthic Primary Producers

As described in **Section 7.9.1**, benthic primary producers provide a range of functions in maintaining a healthy marine environment. In recognition of this, benthic primary producers are protected within Western Australian state waters as outlined in the EPA Guidance Statement No. 29 (EPA 2004a). Four main groups of benthic primary producers are recognised: namely, seagrasses, macroalgae, mangroves and scleractinian corals. Scleractinian corals are recognised as benthic primary producers as they are mostly hermatypic and dependent on symbiosis with phytoplankton embedded in their tissue. The guidelines also protect benthic primary producer communities and their habitat. Benthic primary producer communities are defined as: 'Biological communities, including the plants and animals within which the benthic primary producers predominate'. The benthic primary producer habitat is 'both the benthic primary producer communities as described above as well as the substrata that can/do support these communities'. The same conservation value is given to benthic primary producer communities and the benthic primary producer habitat (EPA 2004a).

During industrial development, adverse impacts to benthic primary producers and benthic primary producer habitat must be limited to the lowest practicable level through measures such as best practice and optimal design. Residual impacts to benthic primary producer habitat must be compared to set threshold levels of acceptable loss set by the EPA as outlined in **Table 7-33**. A cumulative loss within an area is defined as follows (EPA 2004a): 'The sum of all damage/loss of benthic primary producer habitat caused by human activities since European habitation of Western Australia (approximately 200 years before present) and do not include changes to benthic primary producer habitat caused by natural catastrophic disturbances such as severe storms.'

To address the above criteria the total loss of each type of benthic primary producer habitat within the Pluto LNG Development area has been assessed. The following sections address the various steps in the estimation process as shown in **Figure 7-30**.

7.9.9.2 Benthic Primary Producers in the Pluto LNG Development Area

The main types of benthic primary producers present in the Pluto LNG Development area are scleractinian corals and mangroves. Macroalgae and seagrasses are also present but they occur sporadically and in low numbers. A detailed description of benthic primary producers in Mermaid Sound can be found in **Section 6.3.1** with a short summary provided below.

Scleractinian Corals: A total of 229 species of scleractinian corals from 57 hermatypic coral genera have been reported to occur within the Dampier Archipelago, making this area the second most diverse coral region in Western Australia behind Ashmore Reef (Griffith 2004). The most diverse coral assemblages of the Dampier Archipelago are the seaward slopes of outer islands such as Delambre Island, Legendre Island, Rosemary Island and Kendrew Island where the coral communities form fringing reefs in association with the islands (Jones 2004; CALM 2005). Areas supporting a broad variety of corals are also found at Hamersley Shoal, Sailfish Reef and north-west Enderby Island. Physical conditions limit the diversity of corals in the inner Archipelago, with 120 species from 43 genera reported in the inner Dampier Port area (Blakeway and Radford 2005) where historical losses associated with anthropogenic sources are greatest (MScience 2005a). The coral communities in the inner harbour typically grow on hard structures and solid substrata, and show little evidence of actual reef development (URS 2004b; Jones 2004).

The coral in Mermaid Sound can be grouped into five main species associations dominated by *Acropora*, *Porites*, *Pavona*, *Turbinaria* and Faviids/Others, respectively (Blakeway and Radford 2005). The inner harbour species associations from King Bay and Holden Point to Boat Passage are dominated by *Turbinaria* and Faviids/Others, and are typically found in the shallows between 0–10 m (Jones 2004). In general terms the outer communities at Angel and Gidley Island are dominated by *Acropora*, whereas communities dominated by *Porites* are found in the mid-section of Mermaid Sound, such as Conzinc and Malus Island (**Table 7-30**). The species associations generally correlate with the three prevailing environmental factors, namely wave exposure, turbidity and tidal currents rather than peak events such as storms and cyclones (Blakeway and Radford 2005). **Appendix H** lists the scleractinian corals found in the Dampier Archipelago as recorded by LeProvost Environmental Consultants (1991), Blakeway and Radford (2005) and Griffith (2004). All species recorded from the inner harbour are also found in the broader Dampier Archipelago.

The scleractinian coral community structure, cover and distribution within DPA limits is documented in detail in MScience (2005a). Generally corals are found in narrow bands along the shoreline in shallow areas up to 10 m deep. The occurrence of corals is highly patchy with varying degrees of live coral cover. The outer archipelago has been the focus of various studies; however the spatial extent of coral outside DPA limits is poorly mapped. **Figure 6-13** shows the general distribution of habitats throughout the Dampier Archipelago based on data from Bancroft and Sheridan (2000). The current distribution of scleractinian coral habitat within the Pluto LNG Development Management Zones is detailed and illustrated in **Section 7.9.10.5** with distributions within DPA limits based on MScience (2006b) and distribution outside DPA limits based on Bancroft and Sheridan (2000).

Figure 7-30 Flow Diagram Outlining the Process of Benthic Primary Producer Habitat Loss Estimation

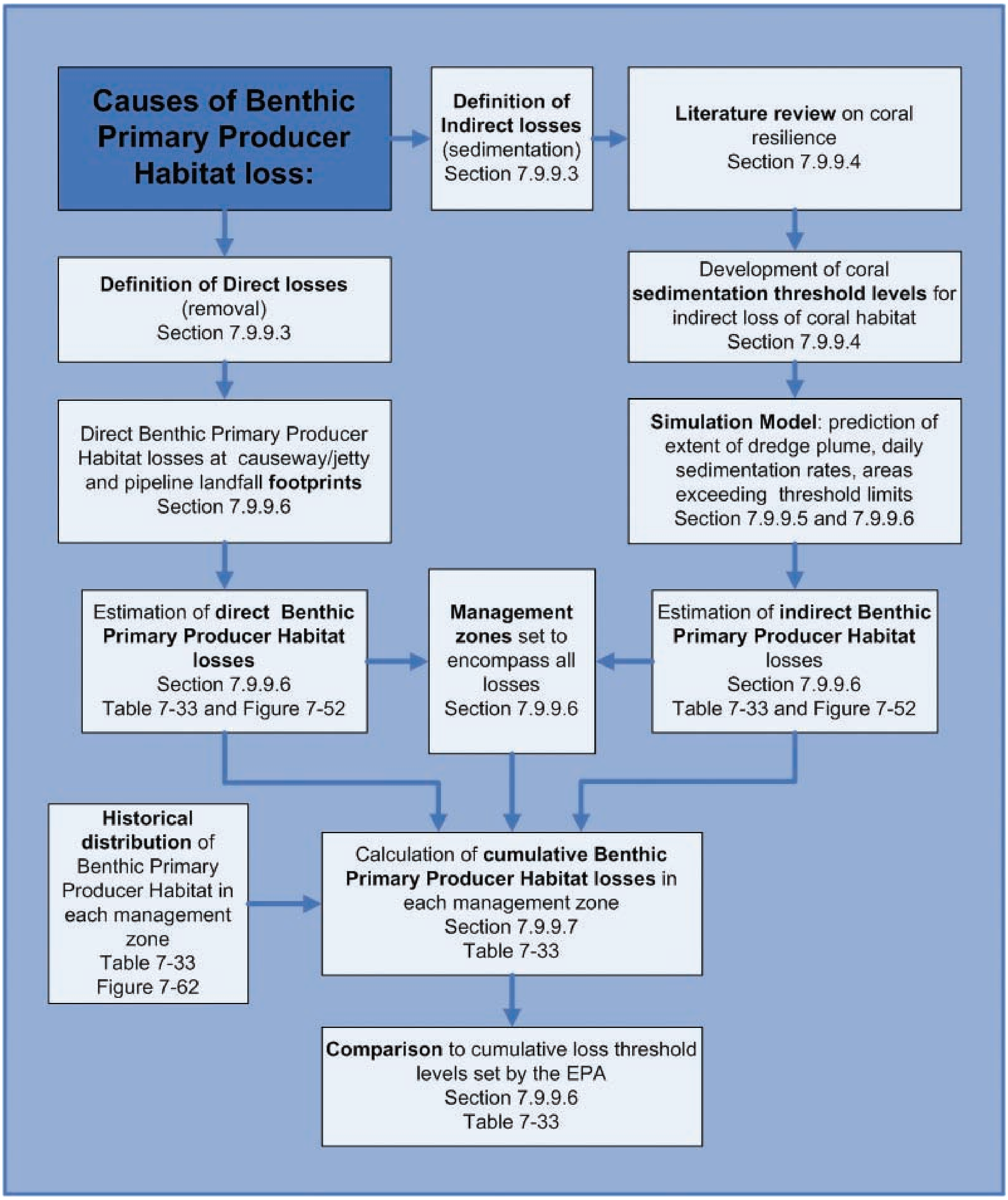


Table 7-30 Coral Assemblages in Mermaid Sound Shown in the Order of Resilience to the Effects of Turbidity (Blakeway and Radford 2005)

Distribution/ Common Occurrence	Coral Assemblage Name	Family	Habitat Characteristics
Inner harbour	*Turbinaria*	Dendrophylliidae	Highly turbid waters
Nearshore inner harbour	Faviids/*Turbinaria*/Others	Favidae Dendrophylliidae	*'Mermaid Sound default community'* Nearshore waters with intermediate levels of exposure, turbidity, and current flow
Inner and mid harbour	*Pavona*	Agariciidae	Relatively sheltered sites with moderate turbidity
Mid harbour	*Porites*	Poritidae	Good current flow with low to moderate turbidity
Outer harbour	*Acropora*	Acroporidae	Relatively exposed sites with low to moderate turbidity

Figure 6-13 indicates the presence of two reefs at the entrance to Mermaid Sound. These low relief subtidal limestone reef platforms typically support a high diversity and density of sessile filter feeders such as sponges and soft corals (which are not benthic primary producers) as described by Bancroft and Sheridan (2000) and discussed in **Section 7.5**.

Anecdotal evidence suggests the existence of a rocky outcrop approximately 5 km north-west of Holden Point. An extensive seabed survey was undertaken in January 2006, where core samples from the proposed navigation channel returned three samples consisting of gravel, a small rock and a sponge, respectively. The locations of these sites are shown in **Figure 6-12** as 'core refusal' in the mid-section of the proposed shipping channel. Other nearby samples returned soft sediment, indicating that the rocky outcrop is limited in size. An extensive survey of the coral distribution in Mermaid Sound (MScience 2005a) did not report the existence of coral in the above mentioned area.

Historical anthropogenic losses of coral within DPA limits have previously been estimated at 1.6–3.6 % (URS 2004b). However, losses are patchy and the majority are attributed to the development of industry in the inner harbour. No widespread losses have been observed on the west coast of Angel Island, adjacent to the existing Mermaid Sound spoil ground A/B, where spoil has been deposited for a number of years (ECOS Consulting 1996; MScience 2006b). It is generally accepted that there has been no anthropogenic losses of the outer coral communities.

Natural causes of coral mortality in the Dampier Archipelago are known to periodically reduce coral cover. In 1989, cyclones Iona and Orson caused widespread damage throughout Mermaid Sound (LSC 1990). In 2004 localised mortality was observed at the south coast of East Lewis Island due to freshwater inundation caused by cyclonic events (Blakeway 2005). Heavy cyclonic influence in 2006 has had a detrimental influence on the coral communities in some parts of the harbour (MScience 2006c). During a recent survey substantial physical damage was observed at two monitoring sites near Malus Island and High Point with an associated 25% decline in coral cover (MScience 2006c). This mechanical damage appears to have been caused by heavy cyclonic influence during the 2005–2006 cyclone season with some additional anchor damage.

As the coral distribution in Mermaid Sound is very patchy, coral cover estimates are strongly dependant on the spatial scale of assessment. Estimates of coral cover recently obtained during the Pluto LNG Development baseline study refer to sites where monitoring transects have been placed deliberately in patches with relatively high coral cover for the area. This monitoring was designed to allow evaluation of change within an area of locally high coral cover, and not to provide an estimate of the coral cover within the general location.

Coral cover at two monitoring sites near Holden Point was recently recorded at approximately 20%. Coral cover at Angel and Conzinc Island sites was recorded at around 30% and 40%, respectively. The estimate of coral cover at the Mid Reef and Hamersley Shoal sites were approximately 20% and 30%, respectively (MScience 2006d).

Mangroves: Mangroves located along the Pilbara coastline are typically restricted to sheltered areas such as estuaries, tidal creeks and sheltered bays (CALM 2002). Within the Dampier region, mangroves are best developed at King Bay, Withnell Bay, Nickol Bay, Conzinc Bay, the Maitland River mouth and on the tidal flats at Regnard Bay (CALM 2002; CALM 2005; Woodside 2005c). Of the mangrove species recorded around Dampier, the red mangrove (*Rhizophora stylosa*) and the grey or white mangrove (*Avicennia marina*) are the most common.

Macroalgae: **Figure 7-43** indicates that limestone reef with macroalgae dominated habitat is widespread around the islands of the Dampier Archipelago. Biodiversity of macroalgae is considered to be high (Huisman and Borowitzka 2003) but species composition and distribution are not well documented. Surveys in 1998 and 1999 by the Western Australian Museum (Morrison 2004) recorded the highest occurrence of macroalgae on isolated patches around Rosemary, Malus and West Lewis Island, but despite surveying several sites on the west coast of the Burrup Peninsula very little macroalgae was found

(**Figure 7-31**). Investigations by Meagher and LeProvost (1979) similarly found macroalgae to occur predominantly outside of the inner harbour.

An extensive seabed survey within the Pluto LNG Development dredging footprint was carried out in January 2006 where surface sediments were collected with a drop core (**Figure 6-12**). None of the samples returned any indication of macroalgae (M Nyegaard [SKM] 2006 pers obs. May 2006), suggesting no or very limited occurrence within the Pluto LNG Development dredging footprint.

Seagrass: Seagrass is generally sparse and occurs in low abundance in Mermaid Sound (Jones 2004; Wells and Walker 2003). A total of nine species have been identified from the Dampier Archipelago (Huisman and Borowitzka 2003), with species from the genus *Halophila* dominating the sparse patches of seagrass found predominantly in the shallow subtidal sandflats in the larger bays of the Burrup Peninsula (Bertolino 2006; Jones 2004; URS 2000; Meagher and LeProvost 1979). Several marine surveys undertaken by the WA Museum (summarised in Hutchins et al. 2004) have consistently reported seagrass as sparse with occurrence at only 2 of 70 stations, 0 of 44 stations, and 8 of 100 stations, respectively. A recent seagrass survey likewise reported the distribution as highly patchy, and the abundance low, with the highest abundance in water depths less than 6 m. The highest abundance of seagrass in the study was found in Withnell Bay, where *Halophila* species were mixed with *Halodule uninervis*, forming patches of up to 2.5 m^2 with a cover between 5–10% (Bertolino 2006).

Figure 7-32 summarises sample sites where seagrass has been recorded by surveys undertaken by Bertolino (2006), Waycott et al (2004), Huisman and Borrowitzka (2003) Walker and Prince (1987), URS (2000) and Meagher and LeProvost (1979). By combining the results of these surveys, good survey coverage throughout Mermaid Sound and Mermaid Strait is achieved, emphasising the sparse and patchy occurrence of seagrass in Mermaid Sound. Sample sites without seagrass are not shown.

An extensive seabed survey within the Pluto LNG Development dredging footprint was carried out in January 2006 where surface sediments were collected with a drop core (**Figure 6-12**). None of the samples returned any sign of seagrass such as rhizomes or leaves (M Nyegaard [SKM] 2006 pers obs. May 2006), suggesting no or very limited occurrence within the Pluto LNG Development dredging footprint.

Figure 7-31 Indicative Macroalgae Distribution in Mermaid Sound

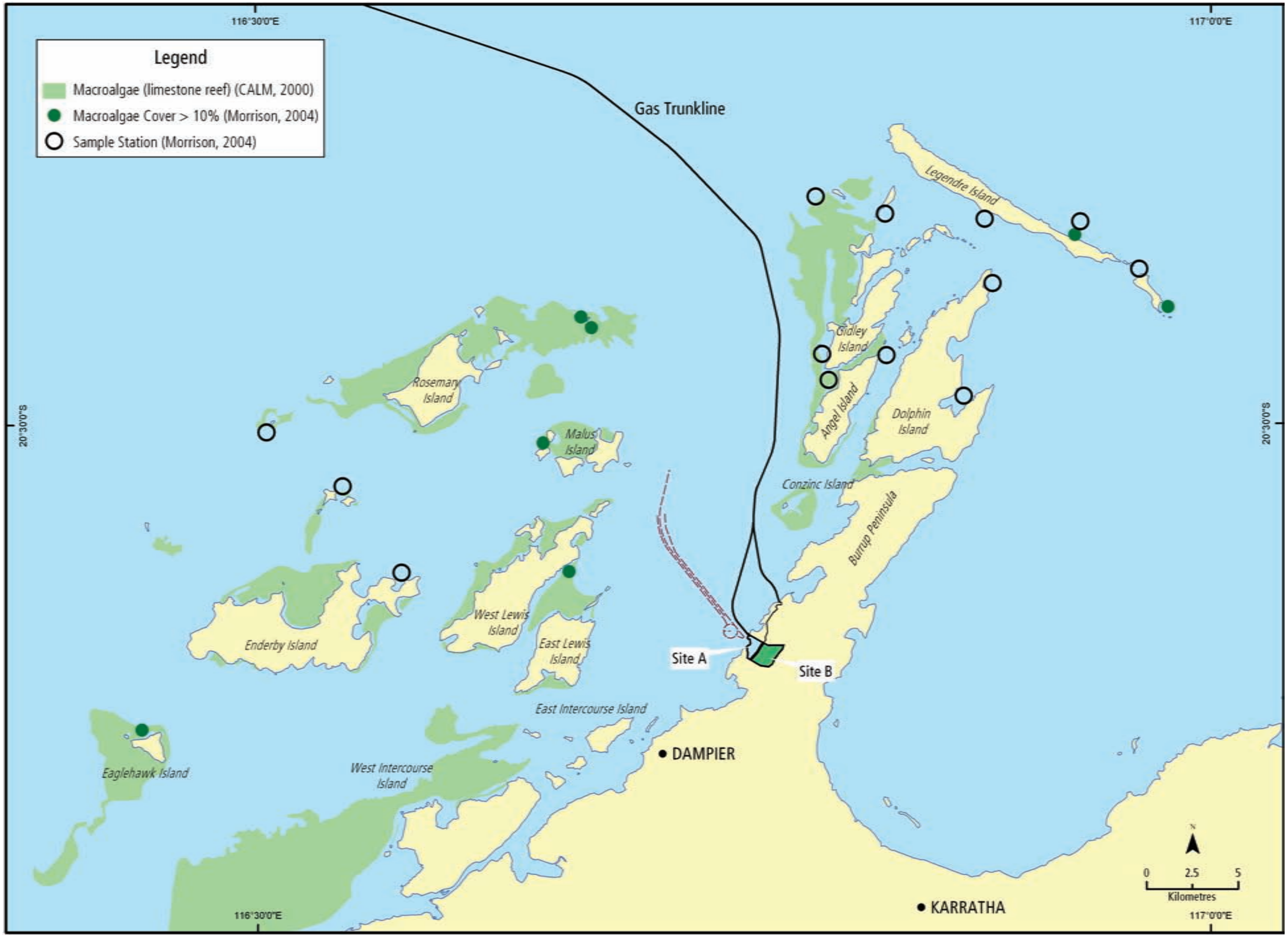
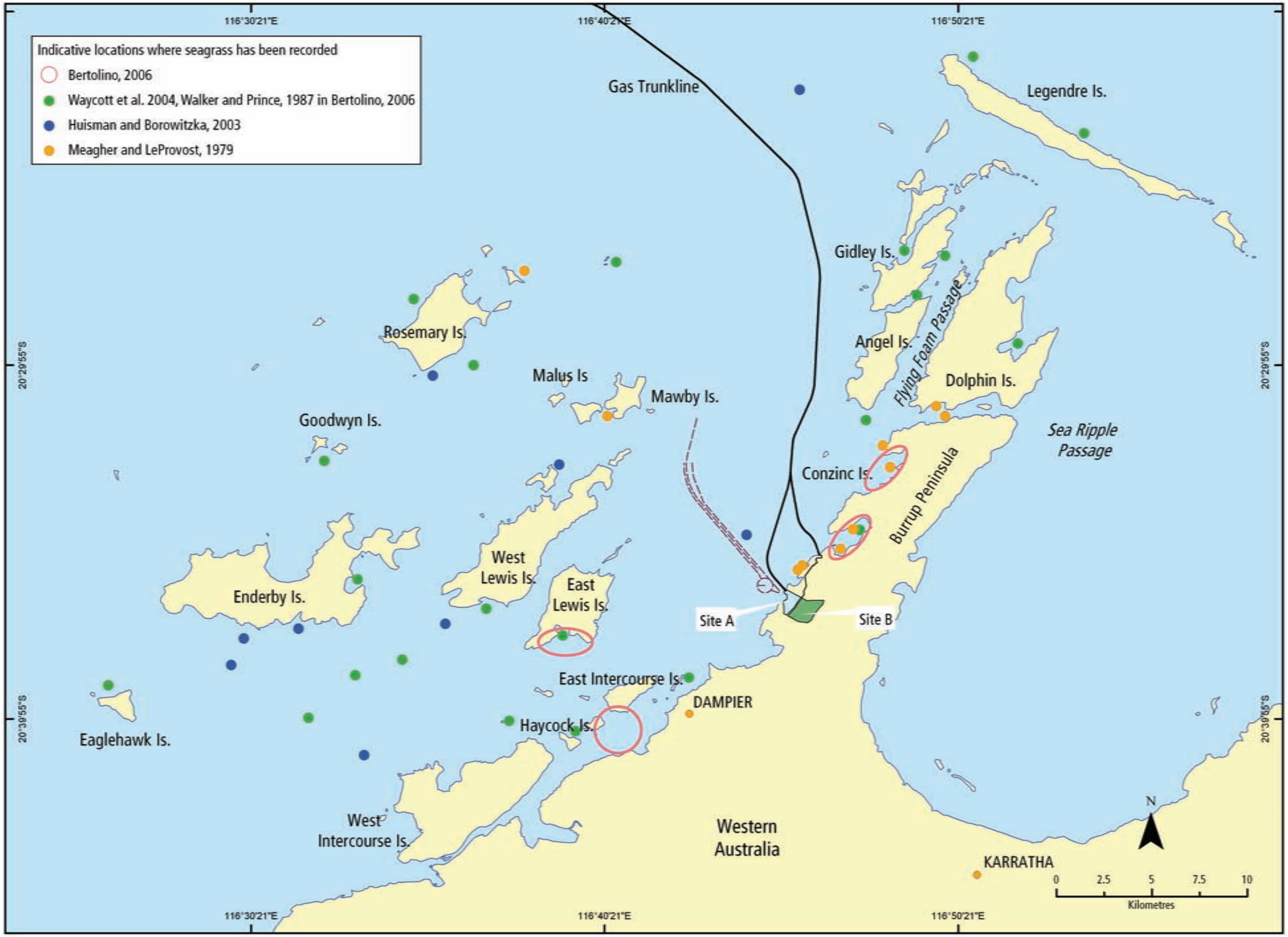


Figure 7-32 Indicative Seagrass Distribution in Mermaid Sound



7.9.10 Effects on Benthic Primary Producers from Dredging, Trunkline and Jetty Construction

The potential impacts on benthic primary producer habitat from dredging and spoil disposal activities, installation of the gas trunkline and construction of the jetty can be attributed to two different types of disturbances: direct removal of habitat and indirect mortality caused by the dredge plume and anchor damage.

Direct Disturbance

Direct disturbances to the seabed and beaches associated with dredging and construction are described in **Section 7.5** and **Section 7.6**. This includes the direct removal of benthic primary producer habitat, and is discussed in detail below. In assessing the potential for direct disturbances to benthic primary producers and their habitat consideration was given to factors that may influence population dynamics, for example, a physically smaller area may not be able to sustain pre-disturbance biodiversity levels with rare species lost or at risk of being out-competed.

Scleractinian Corals: Where scleractinian corals and coral habitat will be removed due to construction activities, the type of impact has been classified as Direct. During the construction of the jetty / causeway and the landfall of the gas trunkline Option 2 at Holden Point, coral and coral habitat will be removed. A 10 m wide construction buffer has been added onto both sides of the jetty footprint in which the coral habitat is considered to be at high risk of direct impact. Coral habitat within this buffer area has been included within the coral loss estimates. Drilling and blasting will remove coral habitat at the shore crossing for gas trunkline Option 2 within a 50 m wide construction corridor. A 50 m band of coral will thus be directly impacted at the trunkline landfall. The area of coral habitat between the jetty footprint and construction corridor for gas trunkline Option 2 will not be removed. However, due to heavy construction influences the mechanical damage is predicted to be extensive, and has therefore been added to the footprint of direct habitat loss (**Figure 7-33**). New coral habitat will also be created as the jetty / causeway and trunkline rock armour will offer new hard substrate for corals to colonise. This will extend into sandy areas where there is currently no coral habitat. Colonisation of these new structures may happen by larvae settlement from communities around the Dampier Archipelago, should the remaining local community be unable to recover and colonise.

The gas trunkline corridor widens to 1.5 km at depths greater than 5 m near Holden Point, within which anchors and anchor line drag have the potential to impact mechanically on coral. There are two rocky outcrops north of Holden Point located within this corridor. These features will be avoided by selective positioning of anchors and associated construction activities, as described in **Section 4.5.3.2** and shown in **Figure 7-34**. The anchor lay barge will require a 300 m radius nearshore for the deployment of anchors as shown in **Figure 4-7** and **Figure 7-34**. Coral habitat located within this radius is predicted to be at risk of mechanical impact from anchor and anchor line drag. As the coral habitat will not be removed, the mechanical impact to the coral is classified under indirect impact. The coral at Holden Point that is at risk of indirect impact from anchor and anchor line drag is located within the area of indirect impact due to sedimentation from construction of the turning basin and berth pocket and is discussed further in **Section 7.9.10.4**.

There are no corals present at the shore crossing or the associated trunkline corridor for gas trunkline Option 1, as shown in **Figure 7-34**. Selective placement of anchors and associated construction activities will avoid nearby sensitive coral habitat, resulting in no direct impact to these communities.

Mangroves: No direct impacts on mangroves will occur during the construction of the Pluto LNG Development facilities.

Macroalgae and Seagrass: Dredging for the navigation channel will not directly disturb seagrass or macroalgae habitat. The seabed within the navigation channel consists largely of silt (**Figure 6-13**), with no evidence of seagrass or macroalgae. Trunkline installation will likewise have no direct impact on either seagrass or macroalgae habitat, as the gas trunkline mainly passes through sand and silt, bypassing limestone reefs along Conzinc, Angel and Gidley islands which have been mapped as macroalgae habitat by Bancroft and Sheridan (2000) (**Figure 7-43**). As seagrass is sparse in Mermaid Sound, and found predominantly in the bays along the Burrup Peninsula and in Mermaid Strait, impacts from direct removal of sandy substrates along the gas trunkline are considered insignificant.

Figure 7-33 Direct Loss of Coral Habitat at Holden Point

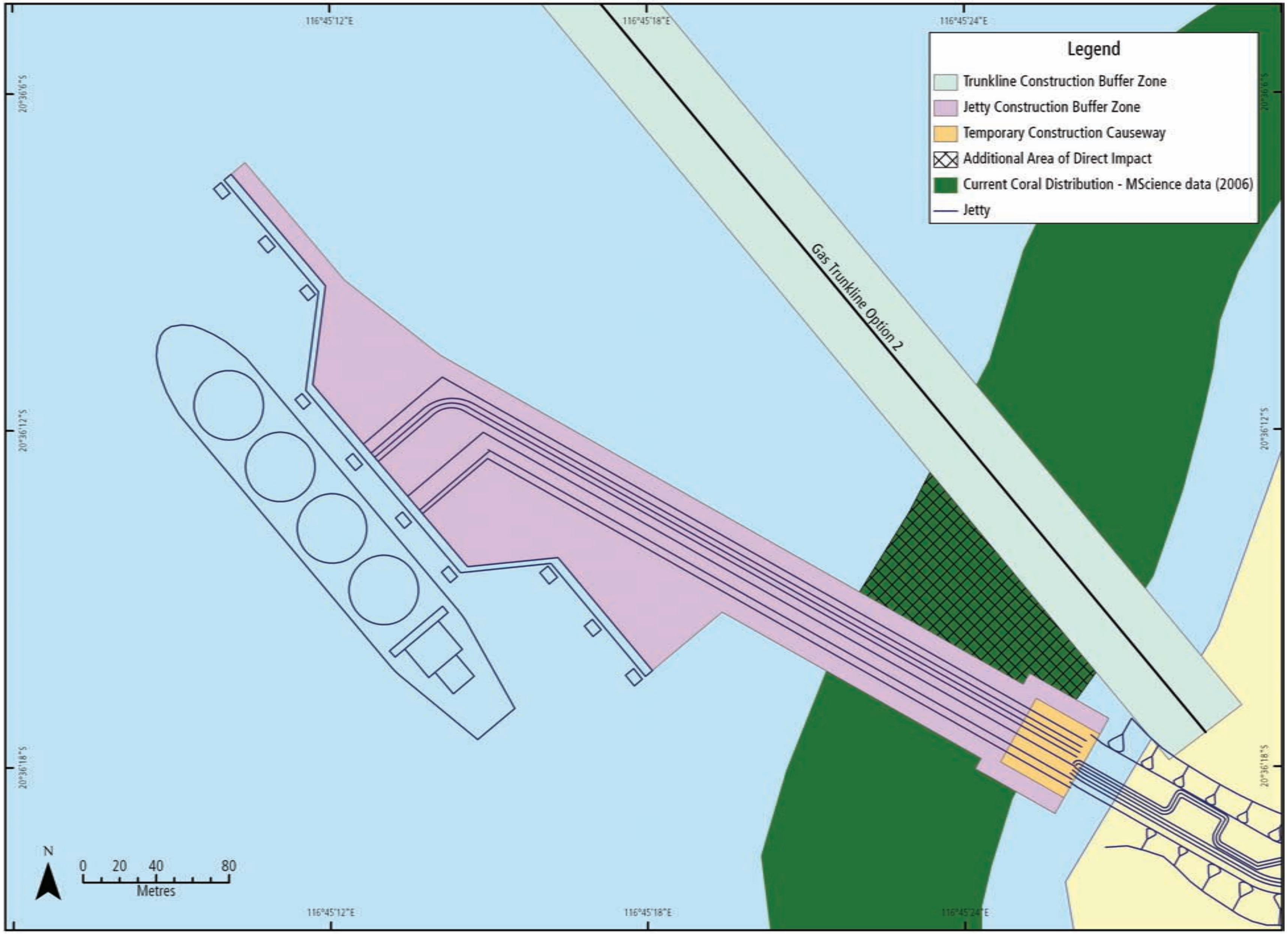
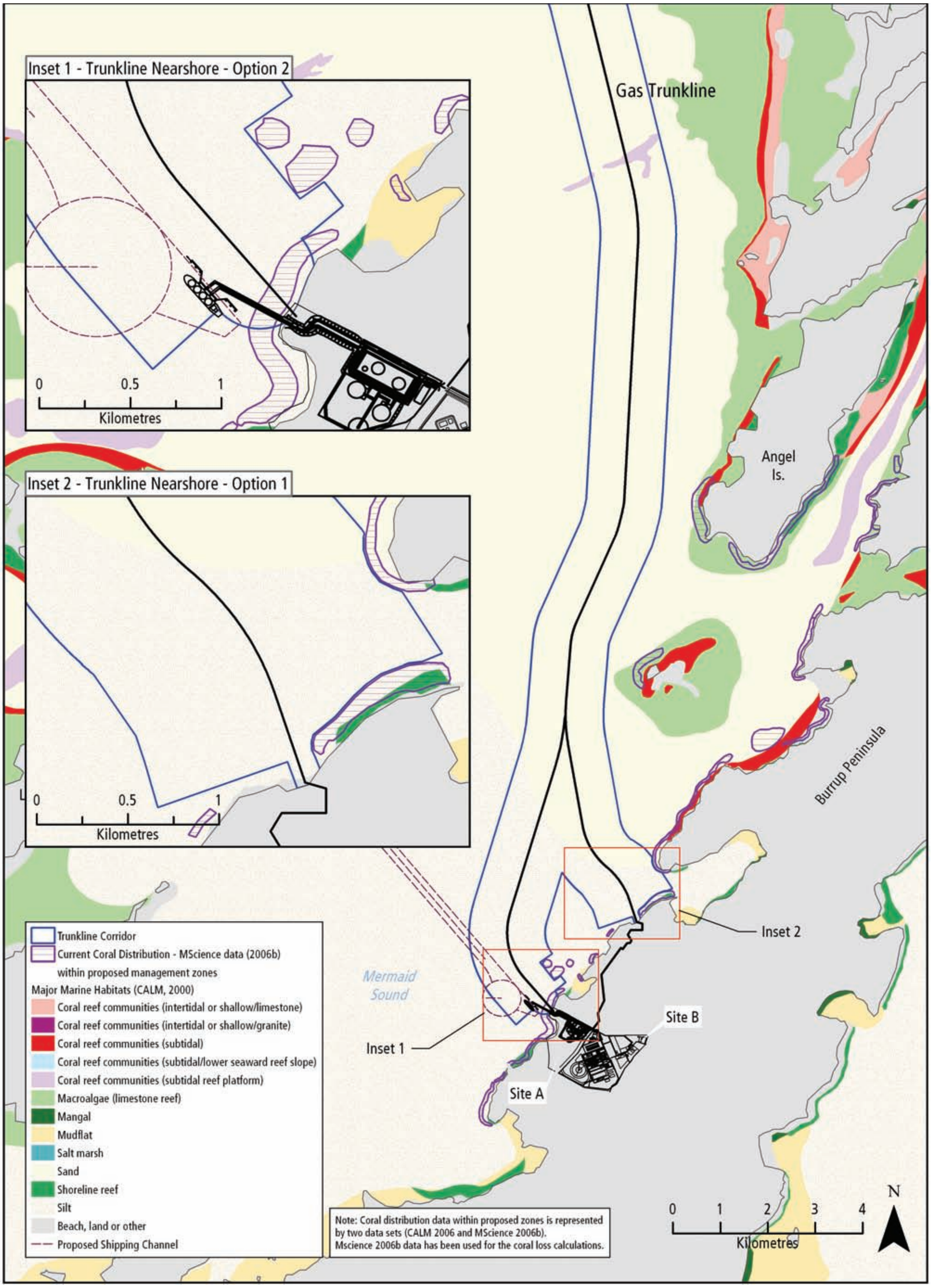


Figure 7-34 Benthic Habitat along the Gas Trunkline Construction Corridor



7.9.10.1 Indirect Disturbance

Indirect disturbances to benthic primary producers from dredging and dredge spoil disposal are caused by an increase in the level of suspended solids. The behaviour of the dredge plume and extent of dispersion will depend on the oceanographic conditions prevailing at the time. Suspended solids may cause increased levels of turbidity and light deprivation for the benthic primary producers located within or underneath the plume, and may in severe cases lead to mortality. Depending on local physical influences on the water masses the suspended solids may settle out of the water column during calmer periods and increase the rate of sedimentation onto the benthic communities underneath. This may lead to abrasion and smothering and widespread physical stress reactions and mortality. Alternatively sediments may remain suspended, or re-suspend shortly after settling on the seabed and eventually get carried out of the area by currents and tides.

Scleractinian Corals: Scleractinian corals are vulnerable to both sedimentation and light deprivation, and of the benthic primary producers found in the Dampier Archipelago, corals are the most susceptible to the effects of dredging. The potential effects are discussed in detail in **Section 7.9.10.2**.

Mangroves: Mangroves are generally not vulnerable to turbidity and low light regimes. Depending on the circumstances and setting, they also tolerate elevated sedimentation levels, although they may succumb to significant events as exemplified by an event in the 1980s where an accidental, large scale deposition of spoil into No Name Bay in Mermaid Sound, led to an unnatural accumulation of sediments across the tidal flats and into mangroves fringing the inner bay. The resulting altered water regime and increased sedimentation caused die-back of mangroves and subsequent impact on establishment and regrowth by propagules (Woodside 1989; V and C Semeniuk 1988).

Modelling results from the Pluto LNG Development dredging programme do not indicate the dispersion of dredge plumes towards mangrove areas, and severe levels of sedimentation are not expected in mangrove habitat anywhere in the Pluto LNG Development area. Significant indirect impacts on mangroves from sedimentation created by dredging are therefore considered unlikely.

Seagrass: Indirect impacts on seagrass from dredging is generally linked to shading associated with elevated levels of turbidity from the dredge plumes. The tolerance to shading varies between species. *Halodule pinifolia* is generally considered tolerant to shading, as a field experiment in the Gulf of Carpenteria showed no reduction in biomass before 38 days of complete shading. In contrast *Halophila ovalis* was in the same study shown to suffer mortality after 38 days of complete shading (Longstaff and Dennison 1999), but is able to regenerate quickly from seeds stored in the sediments (Longstaff and Dennison 1999). *Halophila ovalis* has the widest environmental distribution of all seagrasses and is tolerant to sediment deposition and poor water quality, and is often the first species to colonise disturbed areas (Waycott et al. 2004; Waycott et al. 2005).

Seagrass found in the inner harbour of Mermaid Sound (mainly Withnell Bay and East Intercourse Island) mainly consists of mixed communities of three species from the genus *Halophila*, among them *Halphila ovalis*. *Halodule uninervis* is found among the communities in Withnell Bay (Bertolino 2006). Slightly elevated levels of suspended solids are predicted to occur within Withnell Bay during nearshore dredging during neap tides and south-westerly winds (**Figure 7-20b**). However, as elevated TSS levels are predicted to be short-lived (hours rather than days) no associated impacts on the sparse seagrass in Withnell Bay are predicted. Similarly, nearshore dredging as part of the installation of gas trunkline Option 1 may result in elevated TSS levels in Withnell Bay, due to the proximity of the trunkline landfall. However, the seagrass habitat in Withnell Bay is not likely to be significantly impacted as dredging for the trunkline is of relatively short duration.

Macroalgae: Benthic macroalgae are vulnerable to both sedimentation and to low light regimes, although tolerance varies between species (Eriksson and Johansson 2005). Depending on the situation, these plants may exhibit low light adaptation. Variations in sedimentation and light attenuation have the potential to influence community structure and recruitment success (Turner 2004). However, macroalgae tend to have short life-cycles with seasonal decrease in distribution followed by regrowth, and strong potential for re-colonisation of disturbed areas. Habitat for macroalgae is mainly found in the outer Mermaid Sound, (**Section 7.9.9.2** and **Figure 6-13**) and indirect impact from dredging or spoil disposal is considered unlikely.

7.9.10.2 Indirect Impacts from Suspended Solids and Sedimentation on Scleractinian Corals

Scleractinian corals are vulnerable to both sedimentation and light deprivation, and of the benthic primary producers found in the Dampier Archipelago, corals are the most susceptible to the effects of dredging. The potential effects are discussed further in detail in the following section.

Light Deprivation caused by Suspended Solids: High levels of suspended solids caused by dredging and natural events such as storms and cyclones can cause episodic low light regimes. Sustained reduced light availability for photosynthesis may cause coral bleaching, where the coral losses its symbiotic phytoplankton (zooxanthellae) and becomes starved for energy. Though bleaching in severe cases can lead to mortality, the coral may recover once light levels return to favourable conditions depending on the severity of the bleaching and the duration of impact. An experimental study has shown reduction in colour amongst several coral species during a 10-day exposure to suspended solid concentrations of 165 mg/l. Levels of 199 mg/l caused limited polyp mortality in some individuals

(Rice and Hunter 1992). Whilst a study by Davies (1991) concluded that corals are generally able to survive periodic, short periods of low light regimes (days); total shading for weeks has been observed to cause widespread mortality (Rogers 1979).

The resilience to light deprivation is highly species specific, with more robust corals such as Faviids and species of the genus *Turbinaria* able to live in deeper waters or areas with episodic or chronic low light regimes. Adaptations to low light conditions, including increased chlorophyll concentration and lowered respirations rates, for example, allowed individuals of the species *Stylophora pistillata* to successfully inhabit shaded habitats (Porter et al. 1984). Fabricius et al. (2004) suggests that symbiosis with shading-robust zooxanthellae may allow corals to live in low light regimes. In addition, some species are able to increase their dependence on heterotrophy to compensate for decreased light levels available for photosynthesis (Anthony and Fabricius 2000; Wellington 1982).

The coral assemblages in the inner harbour of Mermaid Sound are comprised of species that generally thrive in deeper waters (Blakeway and Radford 2005). Coral communities in the inner harbour are typically dominated by *Turbinaria* and Faviids on the western side of the Burrup Peninsula, with *Pavona* on the western side around East Lewis Island. The mid-section at Malus and Conzinc Islands are dominated by *Porites*. The outer communities at Angel and Gidley Island are dominated by less resilient but fast-growing *Acropora* species (**Table 7-30**). This zonation is thought to reflect a general trend in turbidity and light availability from the inner harbour to the outer shoals (Blakeway and Radford 2005) though distribution is probably linked to other environmental factors as well, such as tolerance to currents at exposed sites.

Though light attenuation can cause stress in corals (Fabricius 2005) it has not been observed to result in coral mortality during previous dredging programmes in Mermaid Sound. Turbidity levels have previously been observed to peak and quickly return to background levels rather than to build up and result in prolonged periods of attenuated light (Stoddart and Anstee 2005; LDM 1995; LSC 1986; LSC 1987; LSC 1989a). Light deprivation is therefore not considered to be the main cause of coral mortality during dredging. However, periodic low light regimes may contribute further impact to already stressed corals. Likewise, abrasion of corals caused by suspended solids has not been documented as a measurable impact during previous dredging programmes, but may act as a further stress factor.

Sedimentation: Corals have several methods of self-cleaning in relation to particles that may deposit on their surface. This includes mucus production, active rejection by tentacular movement, and polyp inflation/deflation. These methods all require energy. During periods of high sedimentation, energy is relocated from daily metabolic processes, tissue-growth, calcification-rates and reproduction towards these methods of active rejection. As the corals are likely to simultaneously experience low light regimes (that limit the efficiency of photosynthesis), restriction in polyp feeding and increased respiration rates, the corals' energy budget may drop below zero (Philipp and Fabricius 2003; Riegl and Branch 1995; Adbel-Salam and Porter 1988). When the sedimentation load becomes too high for a coral colony to remove, it becomes smothered or inundated in sediment, potentially causing bleaching and mortality in a matter of days (Lee 2005; Philipp and Fabricius 2003; Wesseling et al. 1999; Rice and Hunter 1992; Thompson et al. 1980).

Monitoring programmes in Mermaid Sound since the 1980s have consistently reported limited impact to the coral communities with localised smothering close to dredge and spoil disposal operations the obvious cause of mortality (Blakeway 2005; LDM 1995; LSC 1989b; Meagher and Associates 1984). Acute sedimentation is the most likely factor to cause immediate coral mortality by inundating corals in a layer of sediments they are unable to remove (Nugues and Roberts 2003).

Propeller wash caused by the dredge manoeuvring in shallow areas close to sensitive habitats can cause large amounts of sediments to become suspended and subsequently smother benthic biota. During a 2004 dredging programme in Mermaid Sound, TSS concentrations were monitored in conjunction with coral health and coral cover. Although the coral cover varied throughout the duration of the dredging programme no major stress was attributable to the periodic low light regimes. Only one site was severely impacted with an estimated 80% coral mortality under circumstances where propeller wash resulted in significant heavy suspension of sediments, followed by heavy sedimentation. A nearby site was not impacted, despite experiencing comparable TSS levels with no associated sedimentation (Stoddart et al. 2005). It was concluded that the detrimental effects were the result of heavy sedimentation rather than high levels of TSS and light deprivation (Blakeway 2005).

Considering the turbid environment in the inner harbour of Mermaid Sound, the coral cover and the number of species present may be higher than otherwise might be expected. The number of species present has previously been described as 'surprisingly high' (Blakeway and Radford 2005). However, the coral cover in Mermaid Sound is overall low, and the distribution is very patchy in nature. Naturally high levels of sedimentation have been observed throughout Mermaid Sound (IRCE 2004a) and imply that corals found in the Sound can cope with high sedimentation rates. The trend in species associations from inner to outer harbour, as described by Blakeway and Radford (2005) and summarised in **Table 7-30**, reflects the change in physical conditions, such as turbidity (and thus the ambient light regime) and wave and current exposure (and thus the sedimentation rate) from the inner to the outer harbour. Coral associations dominated by Faviids/Others and *Turbinaria* are found in highly turbid inshore conditions, while *Acropora* dominated communities are found in the outer harbour where conditions are less turbid. This difference in occurrence is most likely caused by a generally higher resilience in the Faviids/Others and *Turbinaria* communities to both periodic low light regimes and higher sedimentation rates compared with *Acropora*.

7.9.10.3 Coral Sedimentation Threshold Levels

While corals are able to remove settling particles from the colony surface, there is a point at which they can become overwhelmed and negatively impacted from deposition of settling particles. While the potential extent of coral loss associated with the Pluto LNG Development dredging programme can be predicted by setting specific coral sedimentation thresholds levels above which mortality may be expected, and modelling the dredge and spoil disposal plumes, there is no categorical level at which corals can be deemed to no longer cope. Threshold levels at which coral mortality occurs, will depend on the species involved, the location and other contributory factors as described further in the following section.

Sedimentation Load, Duration and Re-occurrence: The rate of sedimentation is central to the level of impact on corals, both in terms of load and duration. High sedimentation rates for short periods are believed to create similar stress responses to those resulting from lower sedimentation rates over longer periods. Furthermore, while very high levels of sedimentation will inundate the corals regardless of the frequency with which sedimentation occurs, survival at lower levels of sedimentation rates depends on the duration and frequency of event re-occurrence. While corals may be able to survive one sedimentation event, mortality might result from a re-occurrence of a similar event if insufficient time is available for recovery (Fabricius et al. 2003).

Co-occurring Light Deprivation: Active removal of sediment from the surface of the coral colony requires energy. Co-occurring light deprivation may limit the photosynthesis of the symbiotic zooxanthellae embedded in the tissue of the coral, and deprive the colony of energy. High energy required for sediment removal coupled with light deprivation may limit the ability of the coral to clear itself of settling particles (Abdel-Salam and Porter 1988; Anthony and Fabricius 2000).

Dependence on Autotrophy: When light deprivation is concurrent with sedimentation the coral may experience a decrease in the daily net energy production. An ability to shift energy dependency from autotrophy to heterotrophy may to some degree compensate for the decrease in energy acquired from photosynthesis (Fabricius et al. 2003; Peters and Pilson 1985). Increased amounts of suspended solids in the water column have been shown to add valuable food particles for coral consumption (Anthony 1999), with evidence suggesting that corals from turbid reefs may be more heterotrophic than their conspecifics from less turbid reefs (Anthony 2000).

Sediment Characteristics: The successful removal of accumulated sediment from the surface of the coral colony depends in part on the size of the particles. Removal efficiency for various species has been found to relate to the calus size, with some species removing finer sediments more easily than coarser grains. On the other hand, silty sediments with high nutrient and organic content have been shown to potentially cause severe stress in corals at relatively low sedimentation rates. This has been linked to the formation of a sticky layer on the surface of the coral, with high bacterial activity causing anoxic conditions which trigger severe stress responses in the coral. Such factors will greatly decrease the ability of a coral to clear itself of settling particles (Weber et al. 2006; Fabricius et al. 2003; Fabricius and Wolanski 2000; Stafford-Smith 1993; Abdel-Salam and Porter 1988).

Polyp Size and Colony Morphology: The coral colony morphology greatly influences the amount of sediment collecting on the colony surface. Horizontal plate morphology and cup shapes are naturally more prone to sediment collection than vertical walls and thin branches. The morphology will also influence the ability of the colony to remove settled particles. On a large, flat surface the particles must travel further to reach the edge of the colony, than on a vertical wall where little effort is needed for the coral to push particles off. Furthermore, coral species with large polyps tend to be more resilient to sedimentation due to their larger size, and associated ability to actively remove sediment (Riegl et al. 1996; Stafford-Smith 1993; Labourte 1988; Cortes and Risk 1985; Lasker 1980).

High Ambient Temperature: Bleaching is the state where coral loses the symbiotic zooxanthellae, usually as a result of high ambient temperature, high UV-levels, disease and other stress factors. The consequences are potentially lethal as photosynthesis is depressed or precluded and the coral becomes energy starved. Bleaching will render corals more susceptible to sedimentation stress as less energy is available for active removal of particles (Coles and Brown 2003). Contrasting with this, is the situation during summer bleaching events where increased turbidity related to dredging and spoil disposal may shade the corals and aid in their recovery from bleaching (Jim Stoddart [MScience] pers comm. September 2006).

Pre-Impact State of Coral such as Previous Bleaching: During and after a bleaching event the energy budget of an impacted coral may be altered for months, potentially impacting the reproductive output for more than one spawning season (Michalek-Wagner and Willis 2001). The resilience to sedimentation may likewise be negatively impacted.

Prior Adaptations: Corals inhabiting areas of low light regimes may adapt by increasing the pigment content or size of the photosynthetic units in the zooxanthellae for optimal light uptake. Adaptation to low light levels will make these individuals more resilient to low light levels occurring during dredging. Similarly, there is evidence that corals may increase their temperature tolerance by increasing the proportion of thermal resilient zooxanthellae in their tissue. Such adaptations may increase the resilience of corals to situations where high sedimentation rates are concurrent with low light or high temperature (Berkelmans and van Oppen 2006; Dustan 2004; Labourte 1988; Dubinsky et al. 1984; Porter et al. 1984).

Possibly Other Concurrent Stress Factors – Low Oxygen Levels, High Toxin Levels: Toxins released from contaminated sediments during dredging may potentially lower the resilience of corals to sedimentation and low light levels. Likewise, low oxygen levels from rapid breakdown of released organic material from the sediments during dredging may stress the coral and reduce their ability to remove sediment accumulating on their surface.

Concurrent Sea State and Tide: Rough weather and tidal movement do not directly influence the resilience of corals to sedimentation; however, water movement may aid in re-suspending settled particles and thereby decrease the net accumulation of sediments on the surface of corals. High sedimentation rates are therefore not considered as detrimental during rough weather as during calm periods (Mapstone et al. 1989).

In order to develop applicable thresholds for assessing dredging impacts associated with the Pluto LNG Development, the following local conditions were taken into account in assessing factors that were likely to adversely influence the resilience of corals to sedimentation:

- *Local Turbidity and Sedimentation Conditions:* As Mermaid Sound is a high turbidity environment corals are likely to be well adapted to low light levels and high sedimentation rates.
- *Particle Size and Organic Content of the Sediment to be Dredged and Disposed:* Sediment samples from the dredging footprint indicated that no silty sediments high in organic content are likely to create anoxic layers on the surface of the corals.
- *Main Species Associations found at the Locations of Predicted Impact:* Different threshold levels were developed for the inner and outer harbour species associations to accommodate for differences in resilience.
- *Load and Duration of Sedimentation:* Different thresholds were developed for acute, medium-term and chronic sedimentation for the inner harbour communities, and acute for the outer harbour communities. This reflected the higher likelihood of chronic exposure of sedimentation to the corals in the vicinity of Holden Point.

During the development of sedimentation threshold values, emphasis was placed on previously recorded sedimentation rates from Mermaid Sound. Sedimentation levels in Mermaid Sound have been recorded as high as 240 $mg/cm^2/d$ averaged over five consecutive days (IRCE 2004a) (highest single value 330 $mg/cm^2/d$) but is likely to reach even higher levels during infrequent severe events such as cyclonic disturbances. These rates were recorded while coral monitoring did not detect any impact to nearby coral communities (IRCE 2004a).

The high sedimentation levels recorded in Mermaid Sound are not considered unique in Australian context. The waters around Magnetic Island on the east coast of Australia are another example of a turbid water environment that sustains corals, with recorded sedimentation rates up to 357 $mg/cm^2/d$ (Mapstone et al. 1989). Similarly, Lizard Island in the north-east of Australia sustains a healthy coral reef community whilst experiencing natural sedimentation levels of up to a recorded 658 $mg/cm^2/d$ (Stafford-Smith 1990).

The coral sedimentation threshold levels were developed using existing data on sedimentation rates recorded in Mermaid Sound, in conjunction with observations on coral health as described in detail in APASA and SKM (2006). This review provides an indication of sedimentation rates and associated level of impact. An extensive literature review was undertaken to compare sedimentation rates with experimental data obtained for relevant species (APASA and SKM 2006). However, due to limited existing knowledge and understanding of the reaction of corals to sedimentation and other stresses in Mermaid Sound and elsewhere, the thresholds were developed commensurate with evidence that resilient coral species may be able to survive the set sedimentation rates. With the limited availability of actual field data, the thresholds were developed principally for the use in model predictions and not for management, for which they would be unsuitable.

Table 7-31 outlines the acute sedimentation thresholds for vulnerable species associations (*Acropora* and *Porites*), as well as acute, medium-term and chronic threshold levels for more resilient species associations in Mermaid Sound (*Turbinaria* and *Faviids*/Others). Above any of these thresholds, significant mortality and a decrease in coral cover are expected This is defined as 'moderate impact' as defined in **Table 7-32**.

The absolute sedimentation thresholds in **Table 7-31** do not discriminate in relation to the cause of sedimentation and simply represent the level at which the coral community will suffer mortality with 'moderate impact'. Sedimentation caused by dredging will add to the background level. For the modelling of dredging related impacts the above-background thresholds were used (**Table 7-31**). These values account for the local background sedimentation level, set at 55 $mg/cm^2/d$. The background level was set after considering all available sedimentation rates recorded in Mermaid Sound, including during periods of anthropogenic activity. Such 'un-natural' rates were included in the dataset because the background sedimentation in Mermaid Sound cannot be described as natural where the Sound is continuously affected by the ongoing industrial activities, particularly in the inner harbour. The rate of 55 $mg/cm^2/d$ encompasses more than 90% of all available recordings, thus including all but the most extreme values (APASA and SKM 2006).

The threshold values in **Table 7-31** have been developed exclusively for the purposes of predicting losses of scleractinian coral habitats in Mermaid Sound using modelled sedimentation patterns. Sedimentation trigger values for management purposes will be developed from the results of the baseline study in Mermaid Sound and whose principal aim is to collect continuous data on sedimentation, turbidity and light intensity, coupled with periodic coral monitoring. The study is described further in **Section 7.9.16** and in **Appendix I**.

Table 7-31 Predicted Sedimentation Thresholds for Scleractinian Coral in Mermaid Sound (model use only)

Moderate Impact Sedimentation Threshold	Absolute Sedimentation Threshold (mg/cm²/d)	Above background Sedimentation Threshold* (mg/m²/d)	Duration (Consecutive Days)
Acute – vulnerable species associations (*Acropora* and *Porites*)	250	195	1
Acute – resilient species associations (*Turbinaria* and *Faviids*/Others)	500	445	1
Medium-term – resilient species associations (*Turbinaria* and *Faviids*/ Others)	300	245	5
Chronic – resilient species associations (*Turbinaria* and *Faviids*/Others)	200	145	15

** Calculated as absolute minus background sedimentation rate*

Table 7-32 Definition of Low, Moderate and High Impact

Impact	Cause	Severity	Loss of coral	Loss of habitat
Direct / High impact	Removal of benthic primary producer habitat and substrate.	Severe and irreversible	Yes	Yes
Indirect / Moderate impact	Loss or severe damage of the most resilient species in the coral community due to sedimentation above threshold levels (**Table 7-31**).	Severe but reversible once sediments have cleared	Yes	No
Indirect / Low impact	Sub-lethal impacts including hardly detectable physiological changes to bleaching and disrupted growth and reproduction and changes to the community structure.	Reversible once conditions return to normal	No	No

According to the benthic primary producer guidelines (EPA 2004a): '..where there is a significant risk of both direct loss of benthic primary producer habitat and indirect damage to benthic primary producer habitats to the extent that benthic primary producer communities are lost but the substratum remains largely intact, proponents should assess risk, predict the areal extent of direct and indirect damage/loss and include these areas in the calculation of cumulative loss…'

Table 7-32 outlines three definitions of impact relevant to the calculation of benthic primary producer habitat losses. While direct impact will physically remove habitat with no recovery possible, indirect impact may be reversible once conditions return to normal, and sediments clear. An approximate recovery timeframe of 10–20 years was suggested by Blakeway (2004) for an acute coral smothering event in 2004 in Mermaid Sound, causing an estimated 80% mortality.

7.9.10.4 Predicted Impact

Predicted Impacts from TSS: **Figure 7-23** to **Figure 7-27** show the predicted highest concentrations of suspended solids at any point at any depth for 30 consecutive days of spoil disposal into each of the three spoil grounds: namely, the existing spoil ground A/B, the northern extension of A/B, and the offshore spoil ground 2B. Relevant seasonal examples are shown, according to the planned timing of each disposal operation. The pattern of suspension was investigated by interrogating the model on eight sites of sensitive habitat predicted to experience elevation in TSS associated with the spoil disposal operations. The locations of these sites are shown on each corresponding figure (**Figure 7-23** to **Figure 7-27**). Time series are shown in **Figure 7-35a** and **Figure 7-35b**. Typically, for all sites high levels of TSS can be expected. However, these events are short-lived and levels quickly return to previous levels within hours or days, with no predicted build-up of suspended solids in the water column. This is consistent with the observation of TSS and turbidity levels during two large dredging programmes in Mermaid Sound in 2004 (Stoddart and Anstee 2005). However, many peaks in suspended solids may cause a cumulative impact on the corals from associated light deprivation, especially since dredging for the Pluto LNG Development is scheduled to take place over 24 months. Although the dredging programme is extensive, spoil disposal into spoil ground A/B and its northern extension will be limited to an estimated 4.5 Mm^3 over approximately six to eight months. Spoil disposal of similar magnitude into spoil ground A/B has previously taken place (**Table 7-22**), with little evidence of impacts on corals along the shores off Conzinc Island and Angel Island, and no losses recorded as a result of light deprivation alone (**Table 7-34**). During spoil disposal from other projects into spoil ground A/B in 2004, coral bleaching associated with summer conditions was observed throughout Mermaid Sound, including the communities at Angel Island. Recovery from bleaching at Angel Island was similar to recovery observed elsewhere in Mermaid Sound, indicating that potential stress from turbidity and sedimentation did not prevent coral recovery. It could be speculated that suspended particles may have shaded the corals and reduced the impact of bleaching.

Similarly, modelling of TSS during spoil disposal into deep water spoil ground 2B predicts peaks rather than build up in the level of suspended solids. Only slight elevations of TSS was predicted at the nearest coral reef habitat (north-west of Rosemary Island), which is located more than 6 km from deep water spoil ground 2B. Rough ocean conditions outside Mermaid Sound itself will most likely aid in the dispersion of fine materials, thus preventing a build-up of suspended sediments in the water column and minimising potential impacts such as light attenuation.

No coral losses contributable to turbidity and light deprivation are expected from spoil disposal activities into any of the proposed Pluto LNG Development spoil grounds. In contrast, modelling of dredging of the navigation channel predicts frequent pulses of suspended solids close to Holden Point, where turbidity is likely to prevail for long periods at a time (APASA 2006a). The estimated 12 months of dredging of the turning basin, in close proximity to the coral communities near Holden Point, is likely to pose the greatest potential for turbidity impacts. While no widespread mortality is expected to occur that is solely attributable to shading, this is expected to be a contributing factor to coral impacts near Holden Point, where corals are at risk of being smothered by sediments (see discussion below). Simultaneous light deprivation will almost certainly result in further impact to already stressed corals in this location.

Predicted Impacts from Sedimentation – **Figure 7-36** to **Figure 7-40** present the model output for spoil disposal activities at the spoil grounds A/B, the northern extension, and the deep water spoil ground 2B. The figures show cumulative monthly sedimentation during 30-day periods, with summer, winter and transition months shown. The general pattern of sedimentation was investigated by interrogating the model at five sites with sensitive habitat predicted to experience elevated sedimentation levels. The locations of these sites are shown on each of the corresponding figures. The time series plots show sediment deposition each day during the 30-day simulations (**Figure 7-41**). The pattern of deposition typically demonstrates acute sedimentation events followed by periods with no deposition. This is particularly evident at Site S2, Site S3 and to some extent at Site S4. Such acute sedimentation events, as opposed to lower chronic increases in sedimentation, are considered to be the main cause of coral mortality during the dredging and dredge spoil disposal activities in Mermaid Sound.

Modelling of deposition patterns associated with the dredging of the navigation channel, turning basin, berth pocket and nearshore trunkline installation is described in **Section 7.9.7.8** and APASA (2006a). The model outputs indicate highest deposition patterns at Holden Point during the nearshore dredging of the turning basin and berth pocket using the cutter suction and trailer suction hopper dredges (**Figure 7-42**). Deposition rates in excess of 6000 mg/cm^2/month are predicted near Holden Point, with rates rapidly decreasing to less than 250 mg/cm^2/month within 1.5 km of the uplift area and along a north-east/south-east axis. Cumulative rates below 5 mg/cm^2/month are predicted within approximately 2.5 km of the area.

Trunkline installation through Mermaid Sound is predicted to have little impact on coral habitat. Previous trunkline installations in 1981 and 2004, followed similar routes but at distances of 1–2 km closer to the Burrup Peninsula, than the Pluto LNG Development gas trunkline route, and had little or no impact on corals during installation (**Table 7-34**).

Modelling of the Pluto LNG Development gas trunkline installation in the outer Mermaid Sound predicts limited, localised sedimentation that does not extend to the coral communities that occur along the west coast of the Burrup Peninsula (**Section 7.9.7.10**). Modelling of a trunkline shoreline crossing at a location slightly south of Holden Point predicts low cumulative sedimentation rates, reducing to below 20 mg/cm^2/month within approximately 1 km of dredging activity (APASA 2006a). No impacts on corals are therefore anticipated as a result of trunkline installation, with the exception of the trunkline Option 2 shore crossing at Holden Point, as discussed in **Section 7.9.10**.

Figure 7-35a Monthly TSS Time Series for Selected Locations T1-T4 within Dampier Archipelago

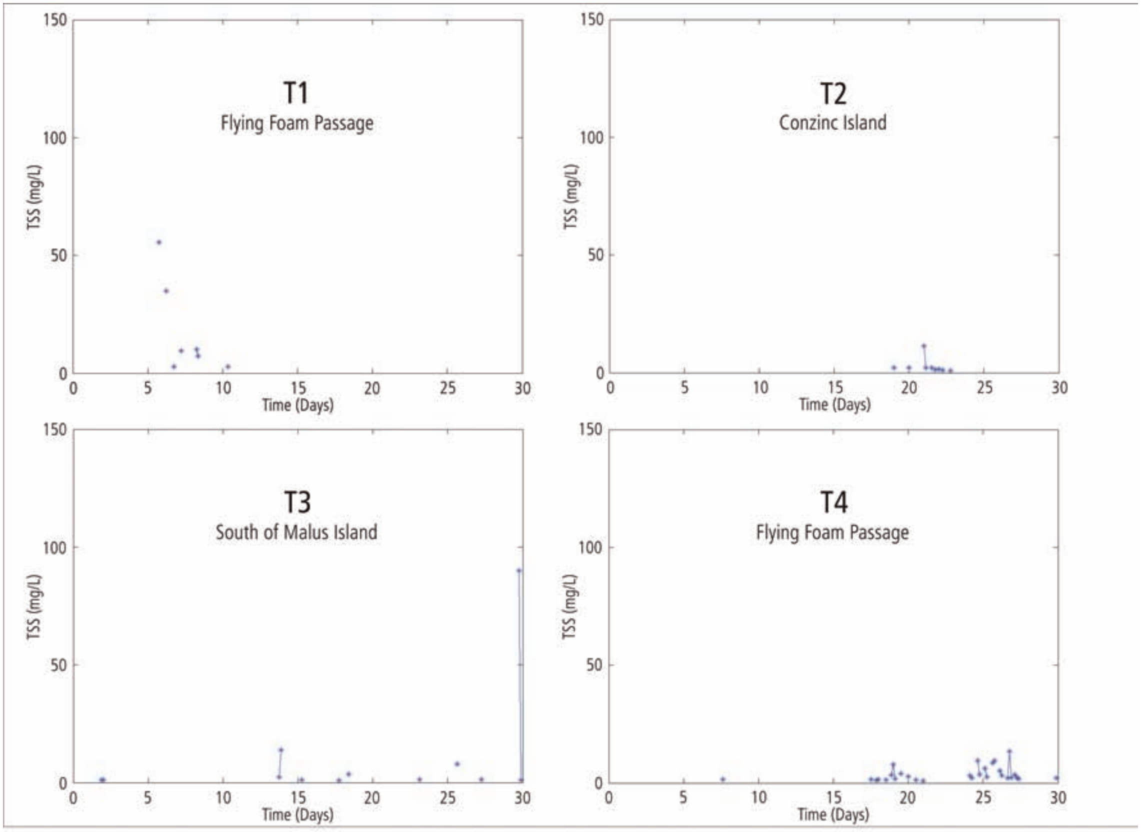


Figure 7-35b Monthly TSS Time Series for Selected Locations T5-T8 within Dampier Archipelago

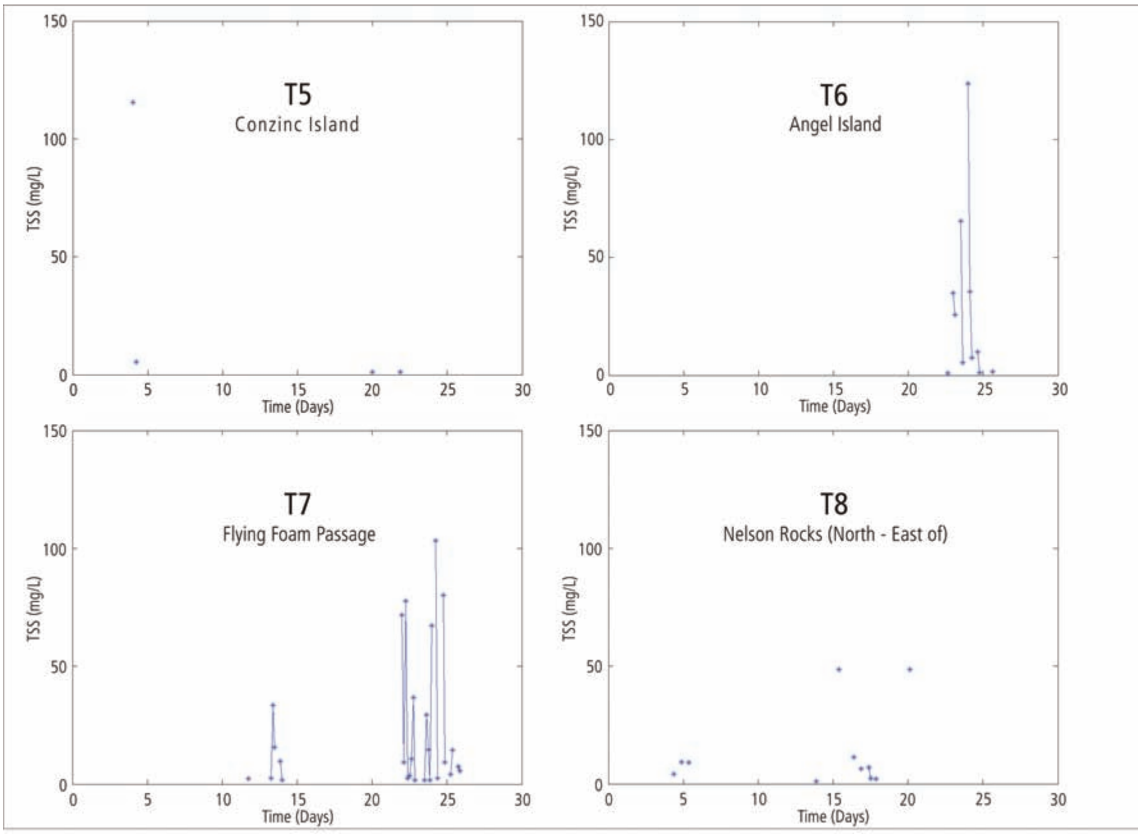


Figure 7-36 Example of Sedimentation Patterns for a Sequence of Disposal Operations into Spoil Ground A/B over 30 days Comprising Fine Material during Winter Conditions

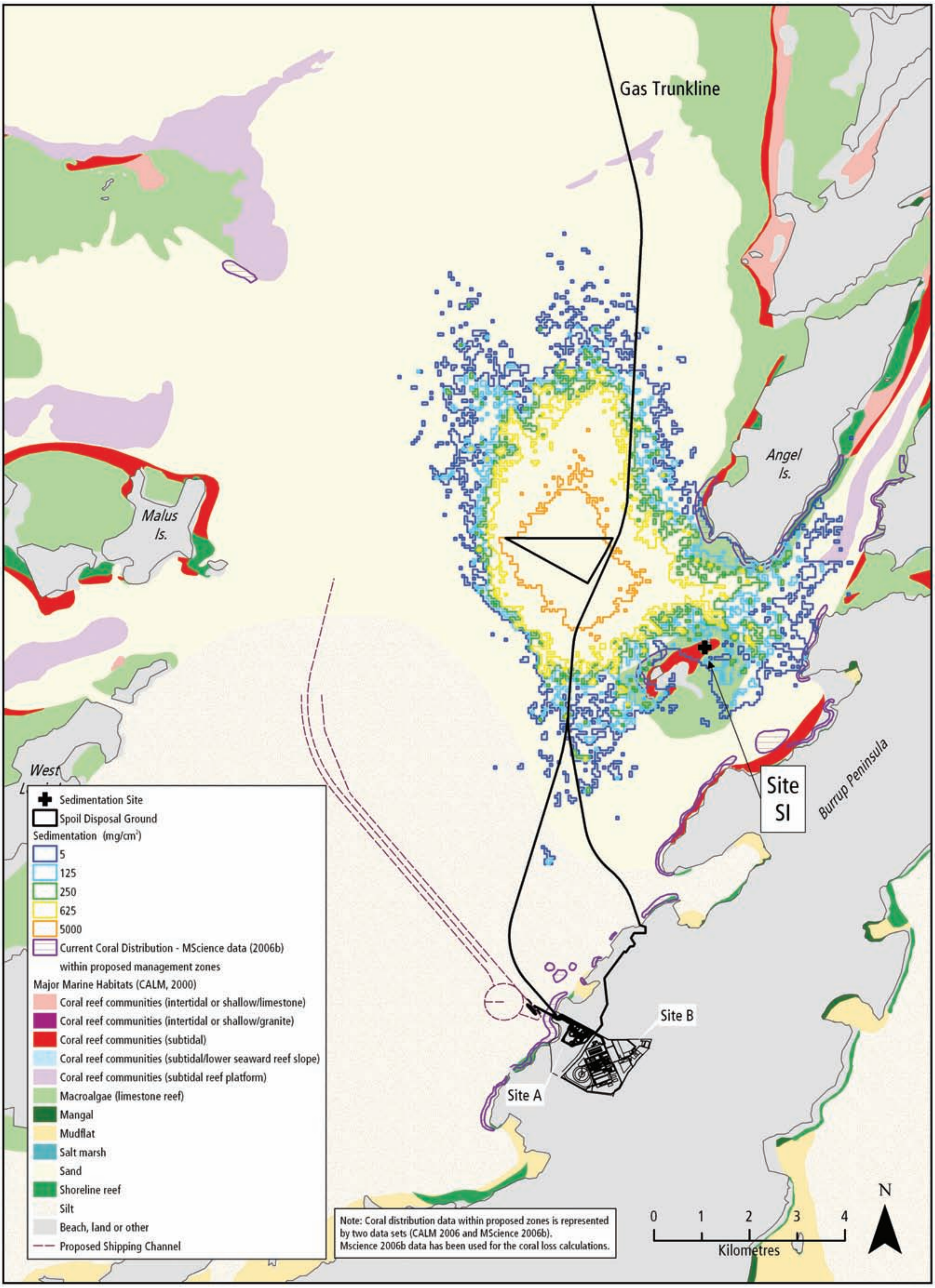


Figure 7-37 Example of Sedimentation Patterns for a Sequence of Disposal Operations into a Northern Extension of Spoil Ground A/B over 30 days Comprising Coarse Material During Transitional Period

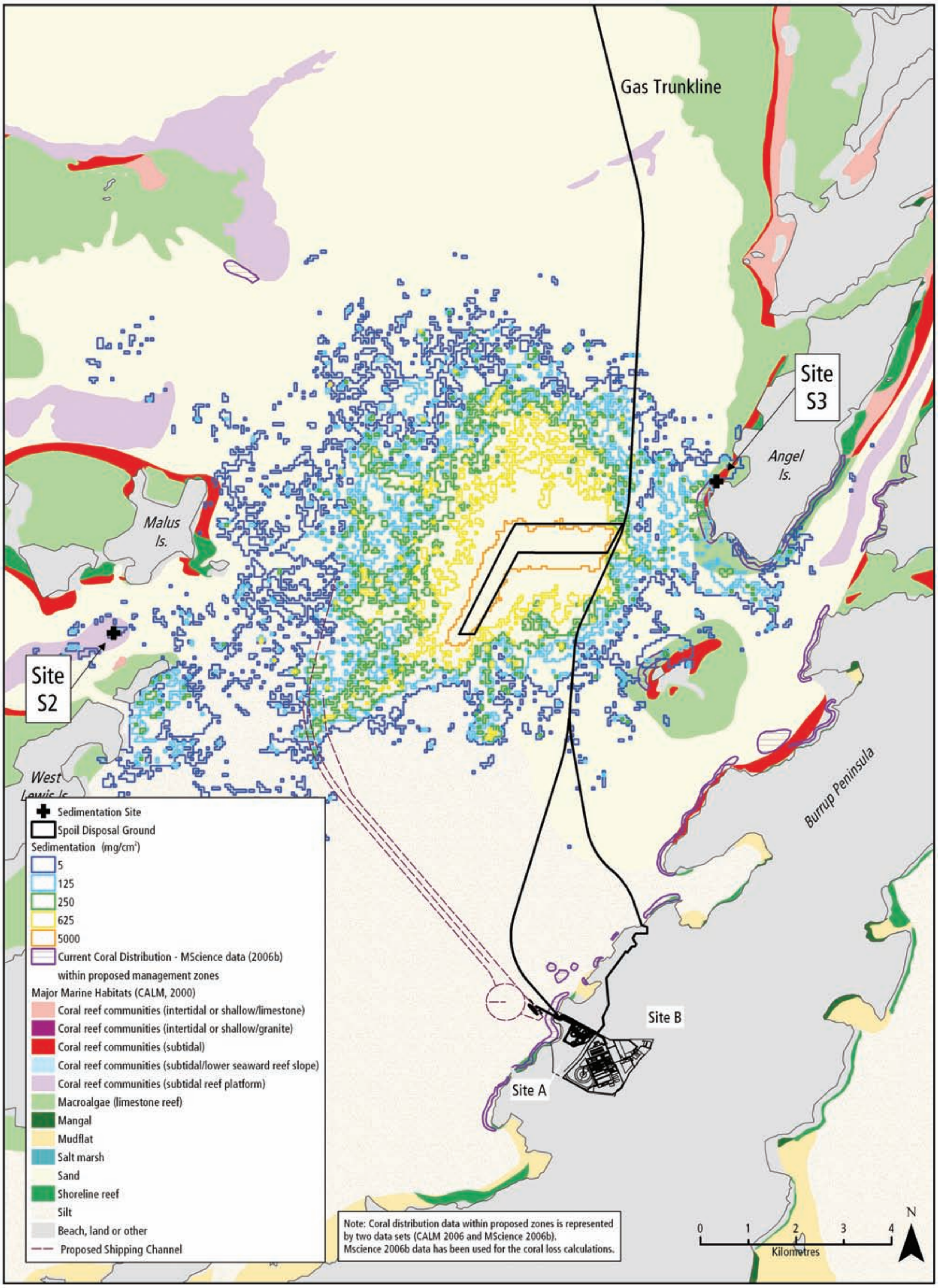


Figure 7-38 Example of Sedimentation Patterns for a Sequence of Disposal Operations into a Northern Extension of Spoil Ground A/B over 30 days Comprising Coarse Material During Summer Conditions

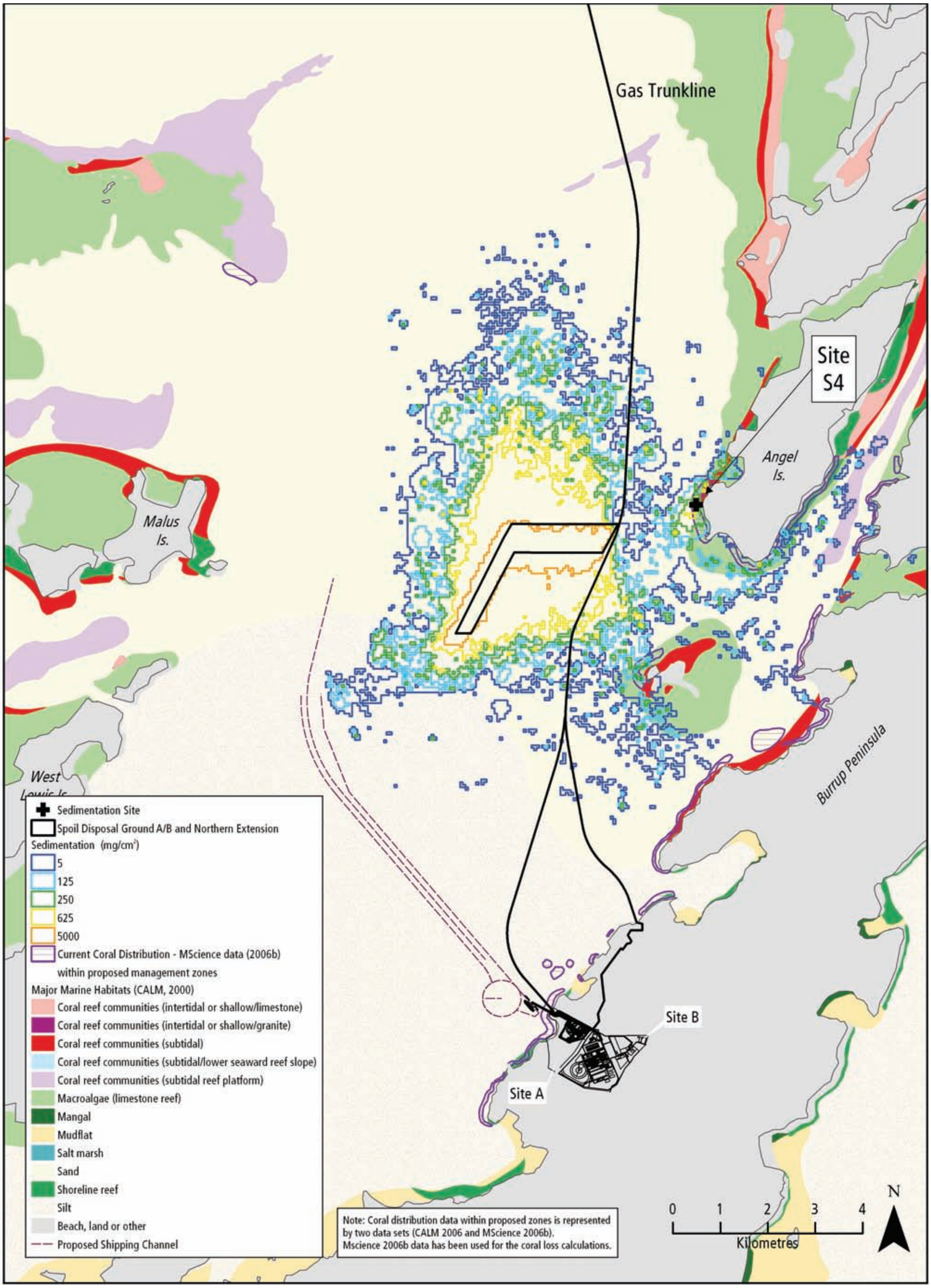


Figure 7-39 Example of Sedimentation Patterns for a Sequence of Disposal Operations into a Northern Extension of Spoil Ground A/B over 30 days Comprising Coarse Material During Summer Conditions

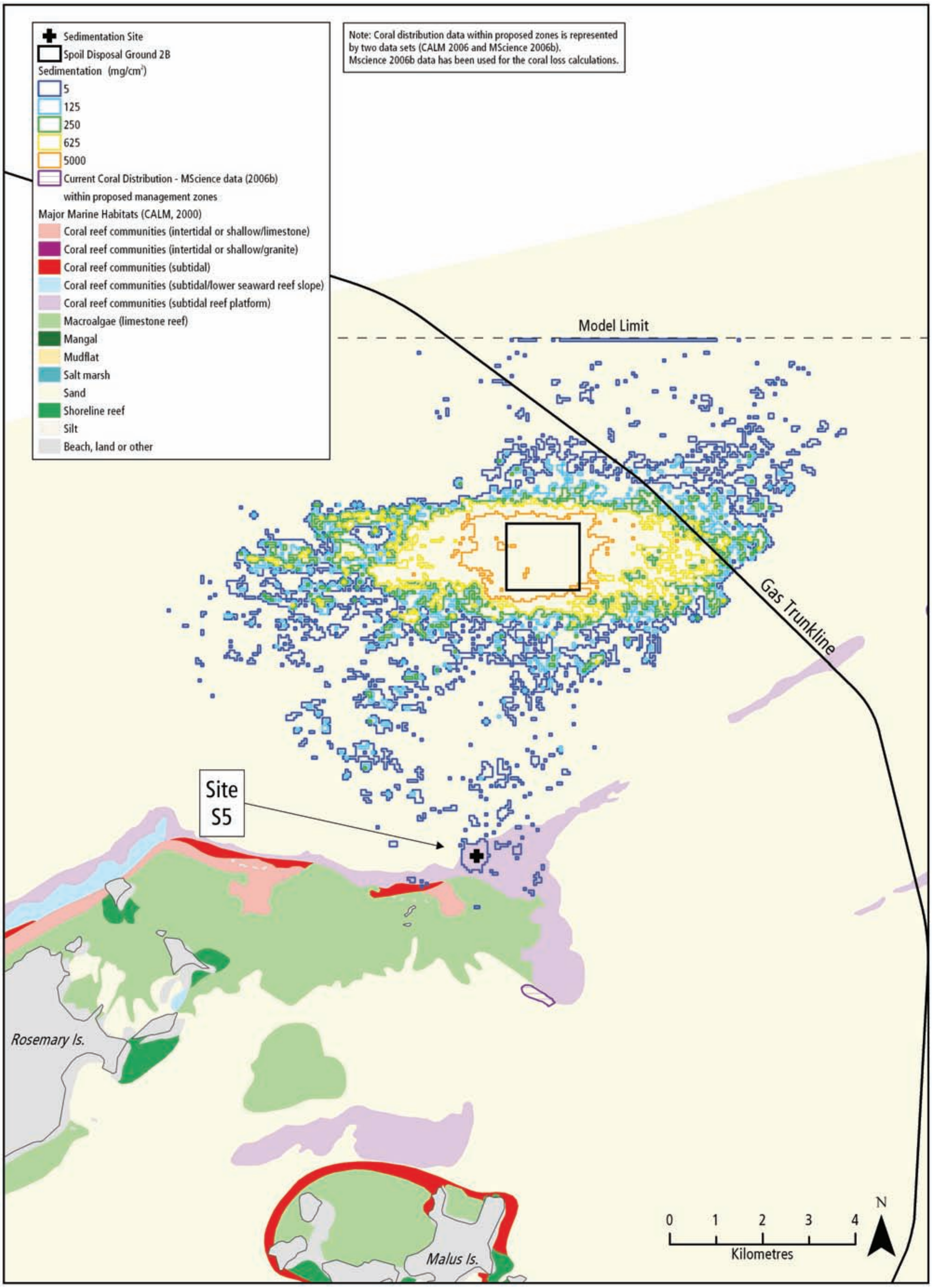


Figure 7-40 Example of Sedimentation Patterns for a Sequence of Disposal Operations into Deep Water Site 2B over 30 days in Winter Months

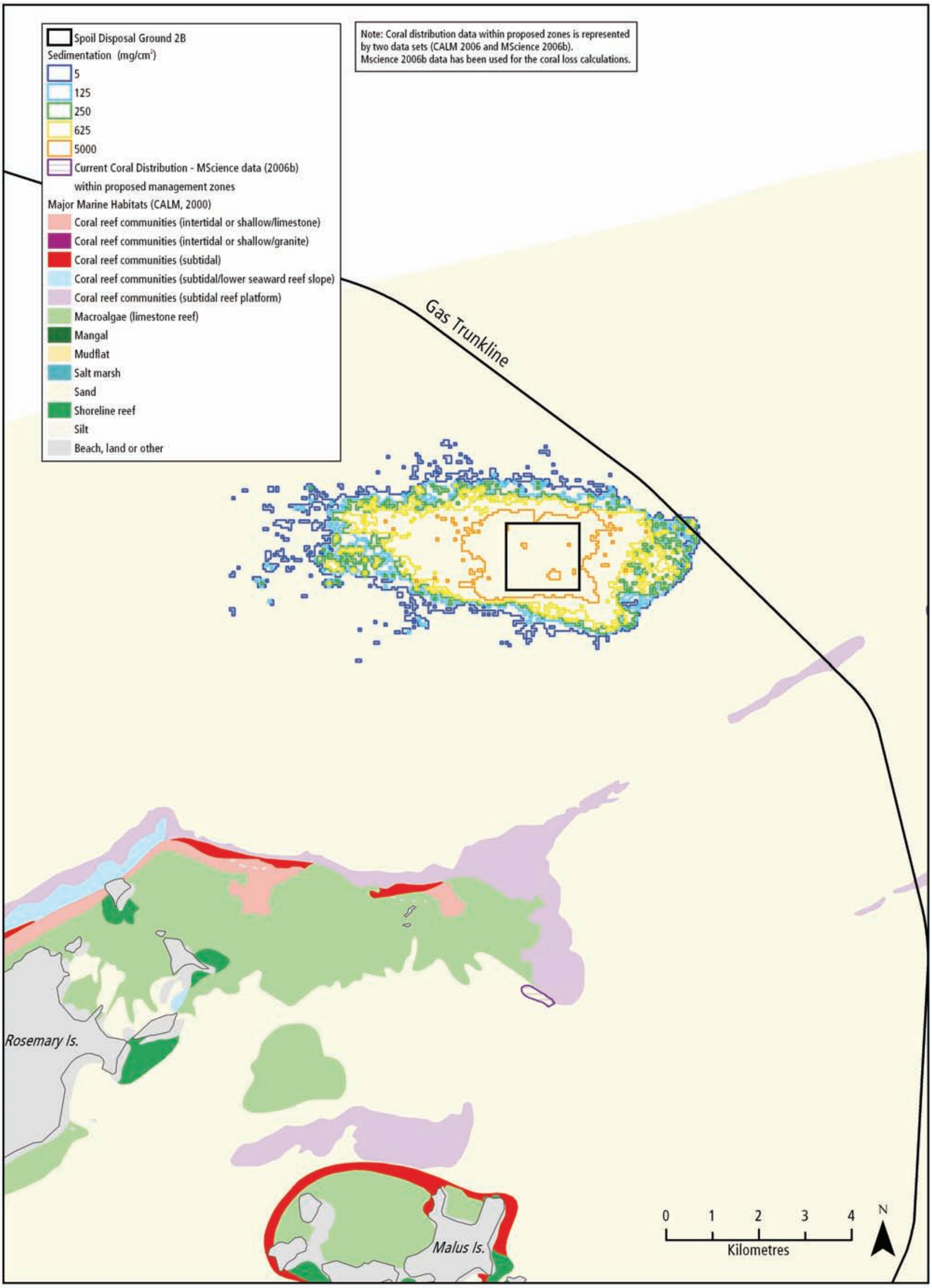


Figure 7-41 Cumulative Sedimentation Time Series over 30 days for Selected Locations Within Dampier Archipelago

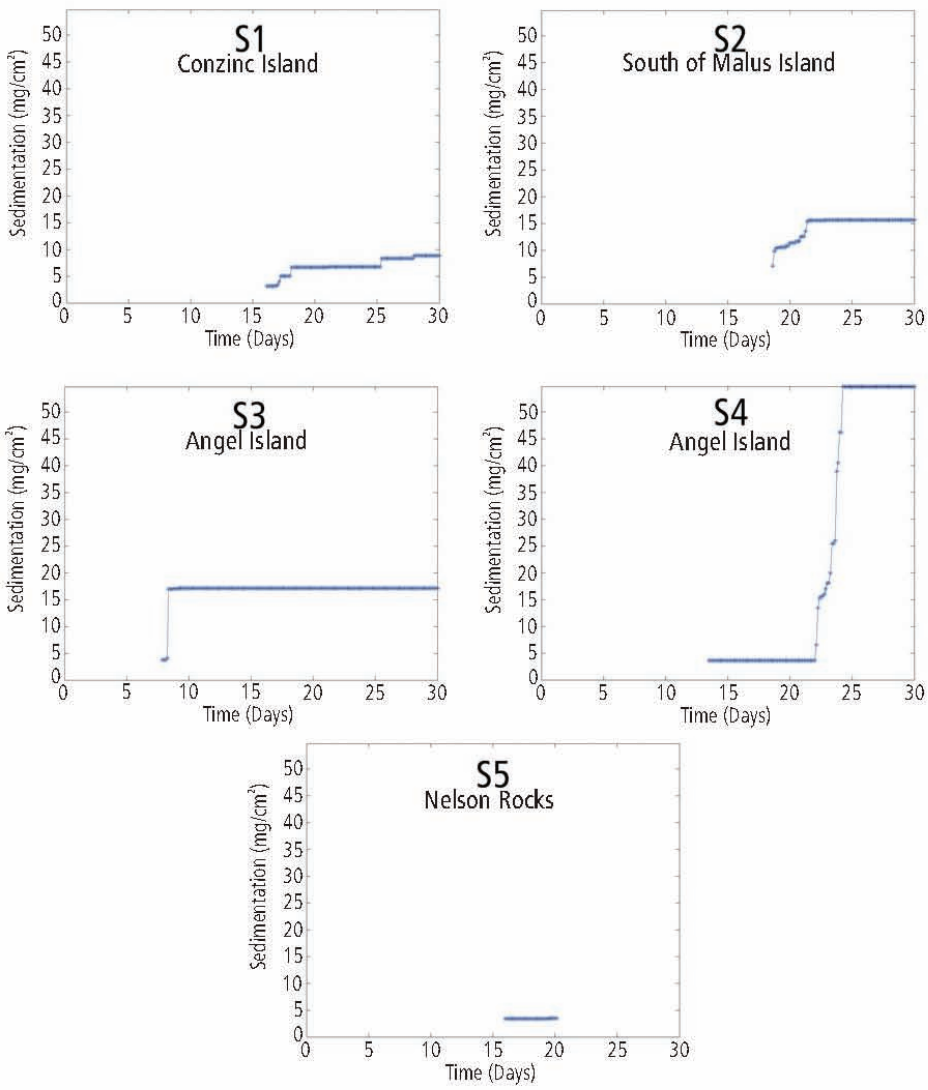
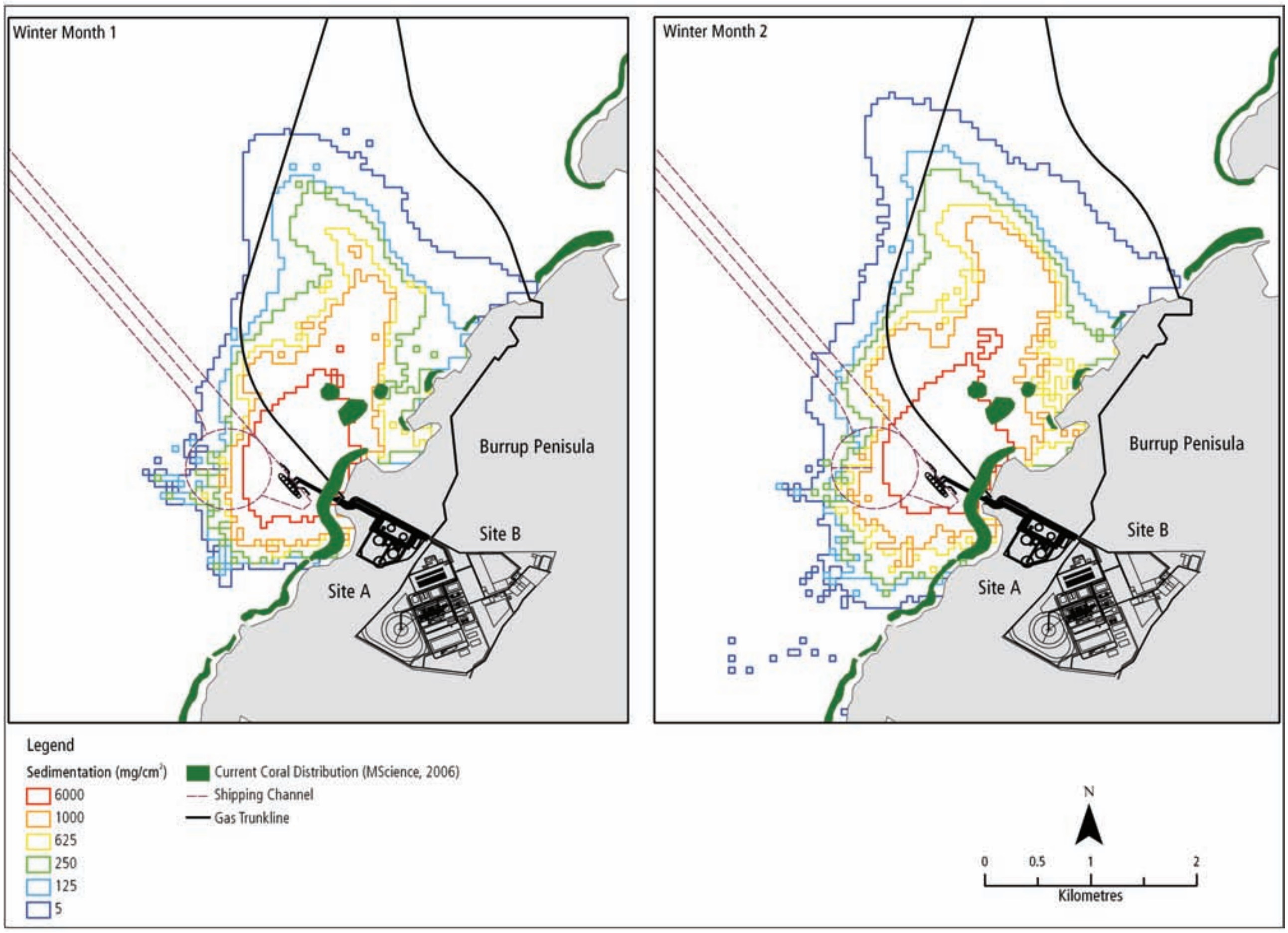


Figure 7-42 Example of the Cumulative Monthly Sedimentation Pattern From Dredging Activities off Holden Point in Winter Season



7.9.10.5 Management Zones and Cumulative Losses of Benthic Primary Producer Habitat

Management Zones: Four management zones for the dredging programme (including trunkline installation) have been developed and are presented in **Figure 7-43**. These zones cover the predicted areas of direct and indirect impact on benthic primary producers and benthic primary producer habitat. Each zone covers approximately 50 km^2 as recommended by the EPA (2004a) and has been determined in conjunction with consideration of DPA limits and biological boundary. The boundary between Management Zones 1 and 2 reflect the boundary of the inner and outer coral communities, respectively, as described by Blakeway and Radford (2005) and summarised in MScience (2005c). Mid-harbour communities (*Porites*) are included in Management Zone 2 which also covers the outer harbour communities (*Acropora*). The boundary between Management Zones 1 and 2 also follows the boundary of the proposed Dampier Archipelago–Cape Preston Marine Conservation Reserve and the associated amended DPA limits (CALM 2005). Management Zones 3 and 4 incorporate outer harbour coral communities, with Management Zone 3 located almost exclusively within the proposed Dampier Archipelago–Cape Preston Marine Conservation Reserve, and Management Zone 4 exclusively within DPA limits.

The cumulative loss threshold set by the EPA that applies to each management zone is outlined in **Table 7-33**. Management Zone 1 is located in the inner harbour exclusively within DPA limits, and is categorised as a development area, which would mean it was within category E. However, Management Zone 1 has already exceeded the cumulative loss threshold of 10% and therefore falls within category F. Management Zones 2 and 3 are each located mainly within the proposed Dampier Archipelago–Cape Preston Marine Conservation Reserves. They are considered high protection areas, and extremely special areas, falling within category B and A, respectively. Management Zone 4 is situated in the outer harbour within DPA limits, and is classified as a non-designated area in category D.

Figure 7-43 Pluto LNG Development Management Zones

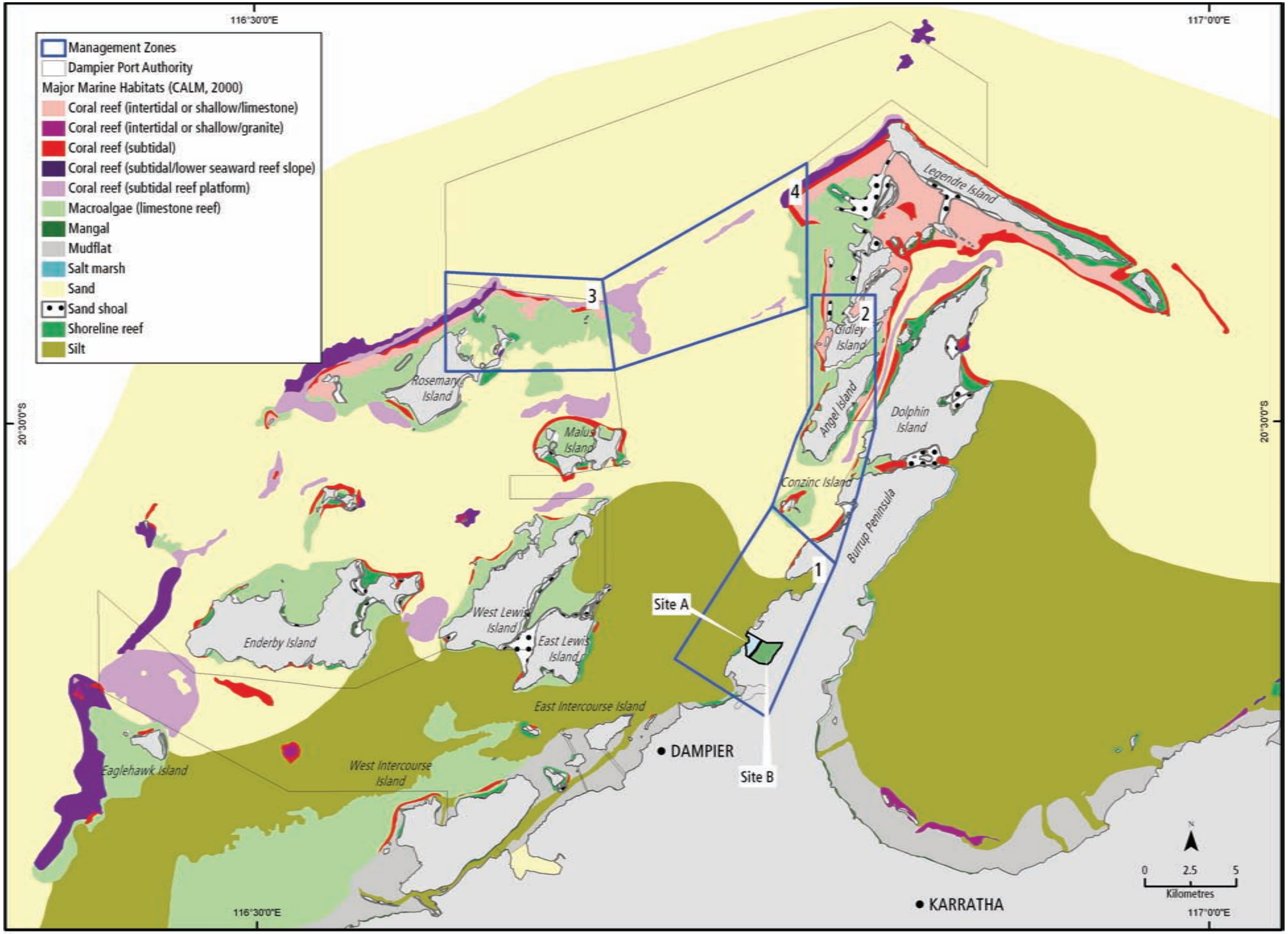


Table 7-33 Acceptable Cumulative Loss of Benthic Primary Producer Habitat

Category	Description	Cumulative loss threshold	Applicable to Pluto Management Zones
A	Extremely special areas	0 %	Corals in Management Zone 3
B	High protection areas other than the above	1 %	Corals in Management Zone 2
C	Other designated areas	2 %	
D	Non-designated areas	5 %	Corals in Management Zone 4
E	Development areas	10 %	
F	Areas where cumulative loss thresholds have been significantly exceeded	0 % net damage/loss (+ offsets)	Corals in Management Zone 1

Source: EPA 2004a

Indirect Impact on Scleractinian Coral Communities: The potential indirect losses of coral due to dredging activities associated with the Pluto LNG Development were obtained by interrogating the sediment dispersion model for dredging and spoil disposal activities (**Section 7.9.10.4**). Individual model cells predicting sedimentation rates above the thresholds (**Table 7-31**) once or several times during the dredging programme were identified.

Figure 7-44 to **Figure 7-48** show the areas where the model predicts sedimentation rates to exceed the acute threshold for vulnerable species (that is, *Acropora* and *Porites*) during disposal into spoil ground A/B and the northern extension. **Figure 7-49** to **Figure 7-51** show the areas where the model predicts sedimentation rates to exceed any of the three threshold levels (acute, medium term and chronic) for resilient species (*Turbinaria* and Faviids/Others) during nearshore dredging for the two worse-case months. This is illustrated in **Figure 7-42**, where the trailer suction hopper dredge and the cutter suction dredge work in tandem in the nearshore area of the turning basin and berth pocket. These areas intersect coral habitat, exceed coral threshold levels and are considered high risk areas, where plume dispersion is likely to cause some level of coral mortality and habitat degradation. The areas above threshold levels consist mainly of areas above the acute threshold. Areas predicted to exceed the medium-term or chronic thresholds during nearshore dredging are limited in extent to within that of the acute threshold, re-stating the prediction that acute sedimentation rather than chronic exposure is the likely cause of coral mortality.

The main areas of potential loss are off Holden Point (due to dredging activities), and patchy areas at Angel and Conzinc Island (due to spoil disposal into spoil ground A/B and the proposed northern extension of spoil ground A/B). No losses are expected from spoil disposal at the offshore deep water spoil ground 2B.

Direct Impact on Scleractinian Coral Communities: **Figure 7-33** shows the expected direct losses of coral adjacent to Holden Point during landfall and jetty / causeway construction. There are overlaps in predicted coral losses attributable to direct and indirect impacts. While management measures and daily operations may be able to limit the indirect losses, the direct losses are unavoidable and irreversible. The new area of hard substrate will be available for coral colonisation and may offset some of the unavoidable losses, but the extent to which this will happen is currently difficult to predict, and hence has not been accounted for in calculations.

Figure 7-52 and **Figure 7-53** summarises the predicted direct and indirect losses from the Pluto LNG Development.

Description of Impacted Scleractinian Coral Communities: As described by Blakeway and Radford (2005) and summarised in **Section 7.9.9.2**, the coral communities in Mermaid Sound can be grouped into five main species associations, according to dominant taxonomic family or genus. **Figure 7-52** and **Figure 7-53** indicate the main species associations occurring at the locations of direct and indirect impact.

Monitoring undertaken from 2004 to 2006 (MScience 2005a; MScience 2006c; MScience 2006d; Blakeway and Radford 2005) has consistently reported associations off Holden Point dominated by Faviids/Others, indicating a diverse group of corals represented by several taxonomic families. The collective group 'Others' includes genera such as *Lobphyllia* (Family Mussidae), *Echinophyllia* (Family Pectiniidae) and *Goniopora* (Family Portidae). The dominating corals in the 'Faviids/Others' species association are the Faviids *Goniastrea australensis* and *Platygyra sinensis* (MScience 2006d), both of which are widespread throughout the Indo-Pacific (AIMS 2006).

The main associations found at Conzinc Island have consistently been reported as being dominated by *Porites* (MScience 2005a; MScience 2006c; MScience 2006d; Blakeway and Radford 2005), with the dominating corals for this community type being *Porites lobata* and *P. solida*, both common and widespread throughout the Indo-Pacific (AIMS 2006).

On the south-western side of Angel Island the coral community has previously been described as being dominated by *Acropora* (MScience 2005a; MScience 2006c; Blakeway and Radford 2005), with dominant corals being *Acropora digitifera*, *A. hyacinthus*, *A. latistella*, *A. millepora* (MScience 2006d), all of which are found throughout the Indo-Pacific (AIMS 2006). However, recent monitoring has observed a change in community structure, from a community that is *Acropora* dominated to one consisting of *Turbinaria* and Faviids/Others.

This shift may have been caused by a decrease in *Acropora* associated with the effects of an intense cyclone season of 2005/2006. Similar widespread mortality of *Acropora* after cyclonic events has been observed previously in Mermaid Sound (LSC 1990). *Acropora* is generally fast growing but susceptible to cyclone damage, and may have a natural cycle of mortality and recovery in the Dampier Archipelago. An alternative explanation for the apparent shift in the coral community is a realignment in transect positions between monitoring programmes using the same site. Due to the highly patchy, heterogeneous nature of coral distribution within Mermaid Sound, slight realignment of transects may result in the survey being undertaken in an adjacent area with less *Acropora*, thus causing the dominant coral in the transect to change (J Stoddart [MScience] pers comm. November 2006).

As described in **Section 6.3.1** and **Section 7.9.9.2** the Dampier Archipelago sustains highly diverse coral communities. However, coral communities in the inner harbour are less diverse and consist solely of corals that are also found in the outer harbour and around the islands of the archipelago (**Appendix H**). It is considered highly unlikely that the outer harbour communities rely on the inner harbour assemblages for provision of spawn and larvae for recruitment and replenishment Therefore impacts on corals of the inner harbour should not have ramifications for the outer harbour communities.

Cumulative Loss of Benthic Primary Producer Communities: **Figure 7-52**, **Figure 7-53** and **Table 7-35** summarise the historical and current distribution of corals in the four management zones. The Current Coral Distribution (CCD) and Current Historical Loss (CHL) within DPA limits were estimated by MScience (2006b) using data collected during several mapping surveys. Current coral distribution outside DPA limits were taken from Bancroft and Sheridan (2000). The Historical Coral Distribution (HCD) before industrial development was calculated as the current coral distribution plus the current historical loss.

The estimates of Predicted High Impact (PHI) and Potential Medium Impact (PMI) from the Pluto LNG Development associated dredging and trunkline installation were obtained as described in this section. The calculations of cumulative loss percentages within each Management Zone were then made using the following methodology, as suggested in EPA (2004):

% current historical loss = (CHL/HCD)*100

% predicted high impact = (PHI/HCD)*100

% predicted medium impact = (PMI/HCD)*100

% predicted cumulative direct impact = ((CHL+PHI)/HCD)*100

% potential cumulative impact = ((CHL+PHI+PMI)/HCD)*100

Discussion: The estimate of benthic primary producer habitat loss presented in this Draft PER represents a 'mid' to 'worse case' scenario.

The estimation of direct impact from jetty construction and trunkline landfall includes a large area in between the two where mechanical damage and sedimentation from construction is likely to cause the coral community to suffer intense mortality. However, the habitat itself in the extended area may recolonise after construction and clearing of sediments by dispersion.

The estimate of indirect impact is also considered mid to worse case. The model predictions of coral loss have been obtained using a theoretical model interrogated with theoretical coral sedimentation thresholds, and are thus only indicative. The model validation study described in **Section 7.9.7.3** (APASA and SKM 2006) confirmed the ability of the applied models used to accurately describe both water circulation and sedimentation rates. While supporting the accuracy of the coral sedimentation thresholds, the model was unable to conclusively validate or reject the coral sedimentation threshold levels given in **Table 7-31**. The estimations of the coral losses associated with the Pluto LNG Development dredging programme are nevertheless considered to be a worse case scenario, based on the conservative nature of the thresholds, as well as the conservative level of background sedimentation rates applied in the impact assessment (APASA and SKM 2006). Furthermore, the modelled sedimentation regime does not take re-suspension into consideration. A landed particle may in reality be removed by wave action soon after settling, thus assisting corals in removing particles.

Notably, inspection of the contour line for the predicted monthly cumulative sedimentation rate of 1000 mg/cm^2/month off Holden Point (**Figure 7-42**) is similar to the predicted area of coral losses (**Figure 7-49**). Outside this contour the sedimentation levels decrease markedly. Cumulative monthly sedimentation of 1000 mg/cm^2 equates to a layer of 4 mm approximately forming on the seabed (APASA and SKM 2006). However, sedimentation rates decrease rapidly with distance away from dredging activity. At a distance of 1.5 km north and south of Holden Point an estimated layer of 1 mm is predicted to form during one month. Even with a layer of 1 mm forming over a short duration (within hours), the corals at Holden Point are considered to be sufficiently resilient to self-clean and to survive (APASA and SKM 2006). A monthly sedimentation rate of 1000 mg/cm^2 equates to a daily average of 33 mg/cm^2/d above background levels. Depending on the actual background level during the dredging programme, a rate of 33 mg/cm^2/d is directly comparable to both observed and predicted sedimentation rates in the validation study where little associated coral impact was observed (APASA and SKM 2006). Consequently, there is reason to believe that potential indirect losses of coral and associated habitat degradation, as a result of the Pluto LNG Development dredging programme will be limited to the footprint as presented in **Figure 7-52** and **Figure 7-53**.

Further support for the conservative nature of the assessment is presented in **Table 7-34** where predicted impacts from the Pluto LNG Development dredging programme are compared to actual coral impacts observed during previous dredging programmes in Mermaid Sound, including a programme located a short distance north of Holden Point. The predicted losses off Conzinc and Angel islands attributable to the Pluto LNG Development dredging programme are considerably higher than impacts observed during previous spoil disposal into spoil ground A/B, despite previous spoil disposal from other projects being of similar spoil volumes and disposal durations to the proposed 4.5 Mm^3 expected from the Pluto LNG Development (**Table 7-22**). Previous monitoring has shown sub-lethal impacts and small losses of coral around Conzinc and Angel Islands possibly associated with disposal into spoil ground A/B (**Table 7-34**). There is no evidence, however to suggest that entire communities and their habitats have been lost.

The estimated losses off Holden Point are comparable to losses associated with the construction and dredging of berth facilities at the existing NWSV Karratha Gas Plant. The percent loss for Management Zone 1 is however, a worse case scenario as more coral habitat is likely to be present within this zone than is currently shown in the coral habitat map of the Dampier Port. More coral may be expected to be present because comprehensive accurate habitat mapping in Mermaid Sound is challenged by the highly patchy occurrence of corals, coupled with low visibility, rendering methods such as aerial photography unsuitable. It is possible, that not all areas of coral are currently mapped (J Stoddart [MScience] pers comm. September 2006).

Summary of losses: Dredging will be required to allow safe approach, berthing and departure of the LNG tankers and condensate tankers, and for protection of the gas trunkline while construction of the jetty and causeway will enable the LNG and condensate to be exported. These activities are necessary for the Pluto LNG Development, which will contribute significantly to state and Commonwealth economic development, including an estimated A$28.6 billion in Gross State Product to Western Australia and direct combined revenue to the Commonwealth and state in the order of A$5.5 billion over the life of the Development.

The coral species within the direct and indirect impact zones are not unique to the Pluto LNG Development area, as they are found elsewhere along the Burrup Peninsula coastline and within Mermaid Sound. As discussed in **Section 7.9.9.2**, coral within the Pluto LNG Development area is patchy and the same species are found in more diverse coral assemblages in other areas of the Dampier Archipelago.

As discussed in the previous sections, it is expected that there will be no direct losses of coral associated with the offshore gas trunkline. Direct losses of benthic primary producer habitat will occur at the gas trunkline Option 2 shore crossing and within the area required for the Site A jetty/causeway which lie within Management Zone 1. These losses will occur during construction, and cannot be avoided; however, losses will be minimised by limiting the disturbance area to that required for construction.

Indirect losses of benthic primary producer habitat are associated with dredging (including trunkline installation). Management strategies to prevent or minimise indirect losses are presented in **Section 7.9.13** and **Appendix I**.

As outlined in the EPA Guidance Statement No. 29, the EPA's objective in Category F designated areas is to ensure there is no net loss of benthic primary producer habitat, and where possible to generate a net gain of benthic primary producer habitat in the area. This is applicable to Management Zone 1, and therefore Woodside is currently investigating various options for environmental offsets, and is considering a possible combination of primary and secondary offsets to mitigate environmental impacts. Primary offsets directly counterbalance the environmental impact (for example, creation of artificial habitat) and secondary offsets aim to complement and assist the primary offset (for example, protection or monitoring programmes). Environmental offsets will be discussed with stakeholders and local community groups as part of the offset planning process.

Figure 7-44 Areas Predicted to Exceed Coral Sedimentation Threshold Levels During 30 Consecutive Days of Spoil Disposal into A/B Comprising Fine Material during Winter Conditions

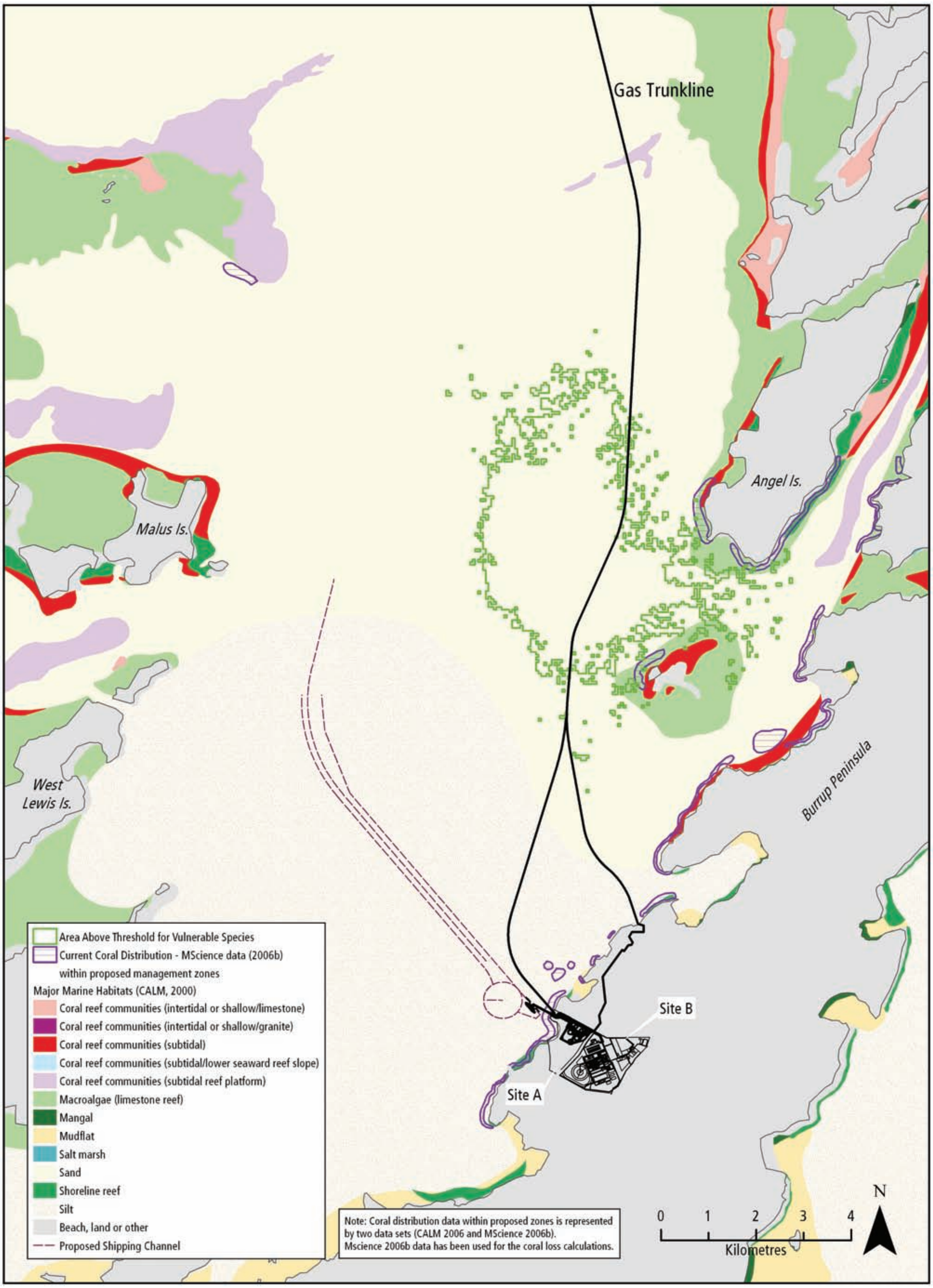


Figure 7-45 Areas Predicted to Exceed Coral Sedimentation Threshold Levels During 30 Consecutive Days of Disposal into Northern Extension of Spoil Ground A/B Comprising Coarse Material during Summer Conditions

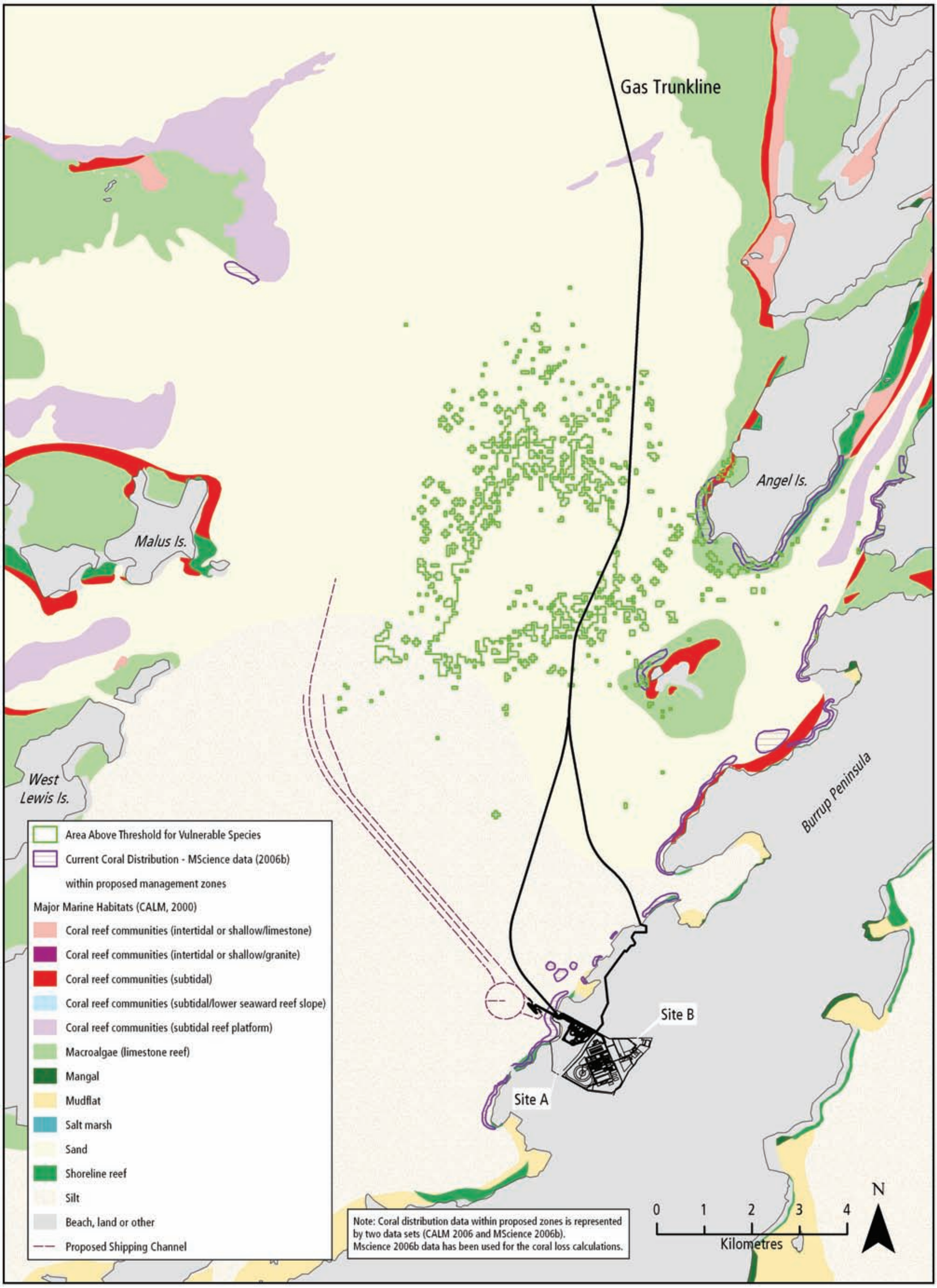


Figure 7-46 Areas Predicted to Exceed Coral Sedimentation Threshold Levels During 30 Consecutive Days of Disposal into Northern Extension of Spoil Ground A/B Comprising Coarse Material During Transitional Period Conditions

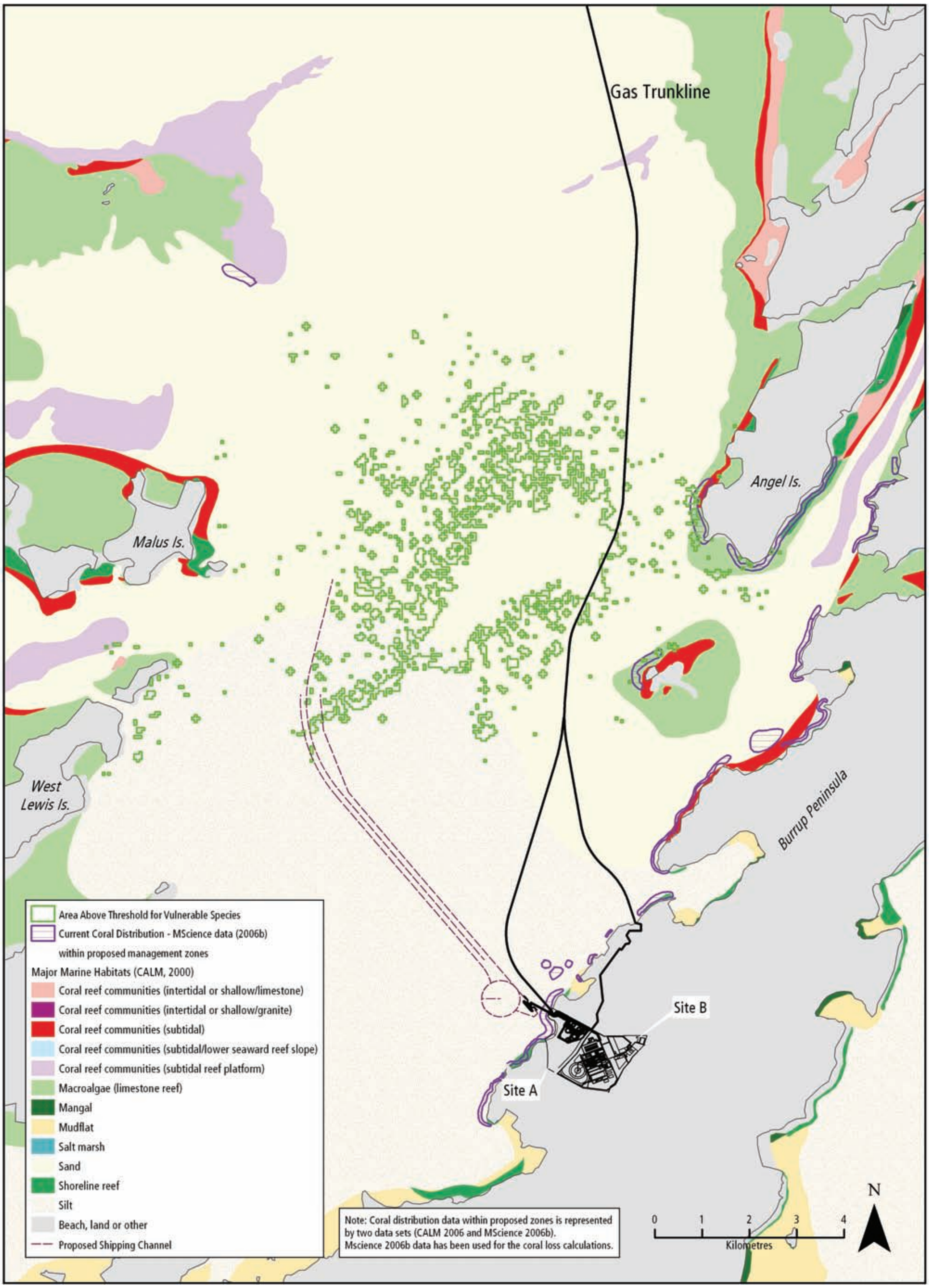


Figure 7-47 Areas Exceeding Coral Sedimentation Threshold Levels as Outlined in Table 7-31 During 30 Consecutive Days of Spoil Disposal into the Offshore Deep Water site 2B in Summer Conditions

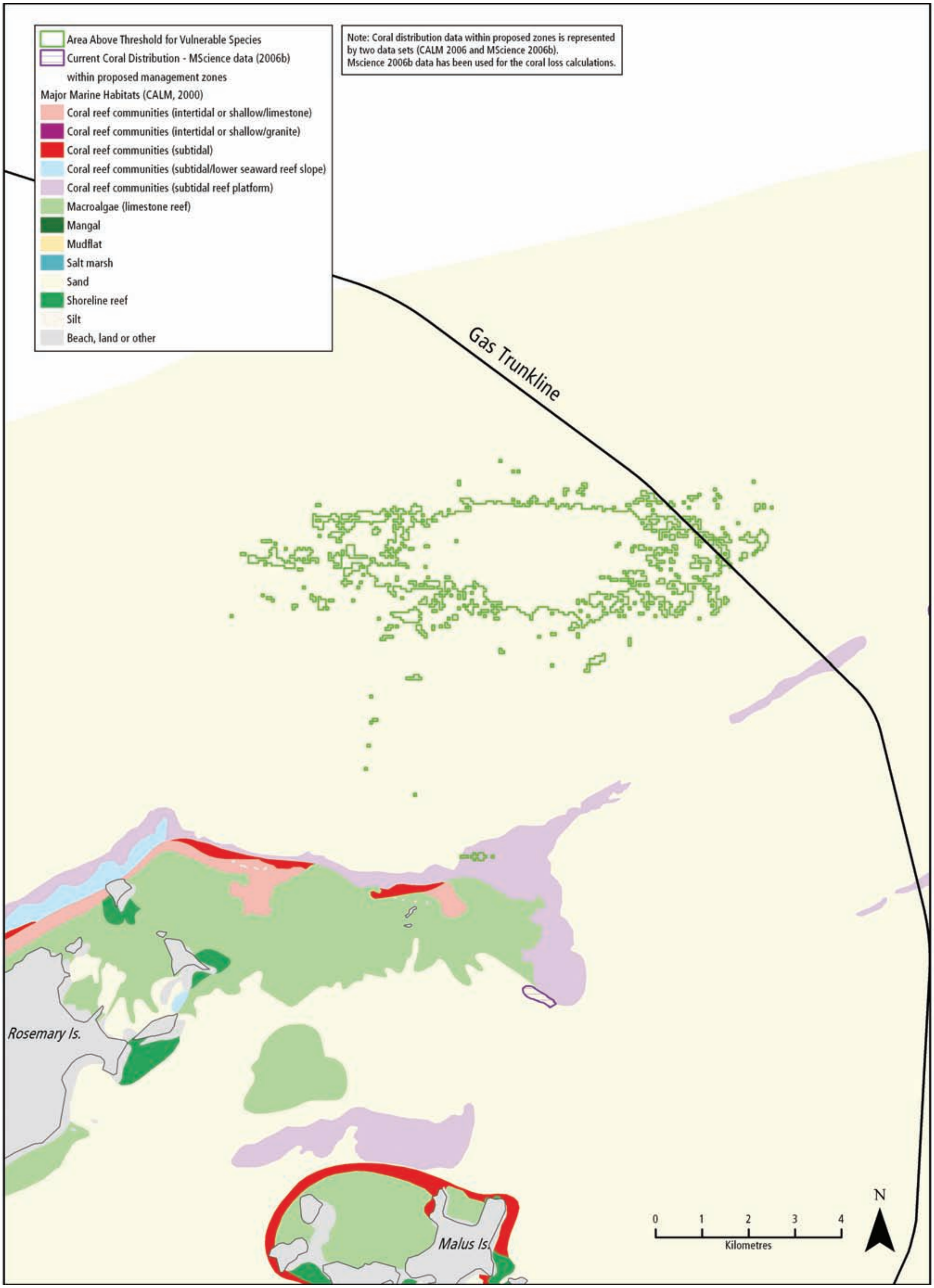


Figure 7-48 Areas Exceeding Threshold Levels as Outlined in Table 7-31 During 30 Consecutive Days of Spoil Disposal into the Offshore Deep Water Site 2B in Winter Conditions

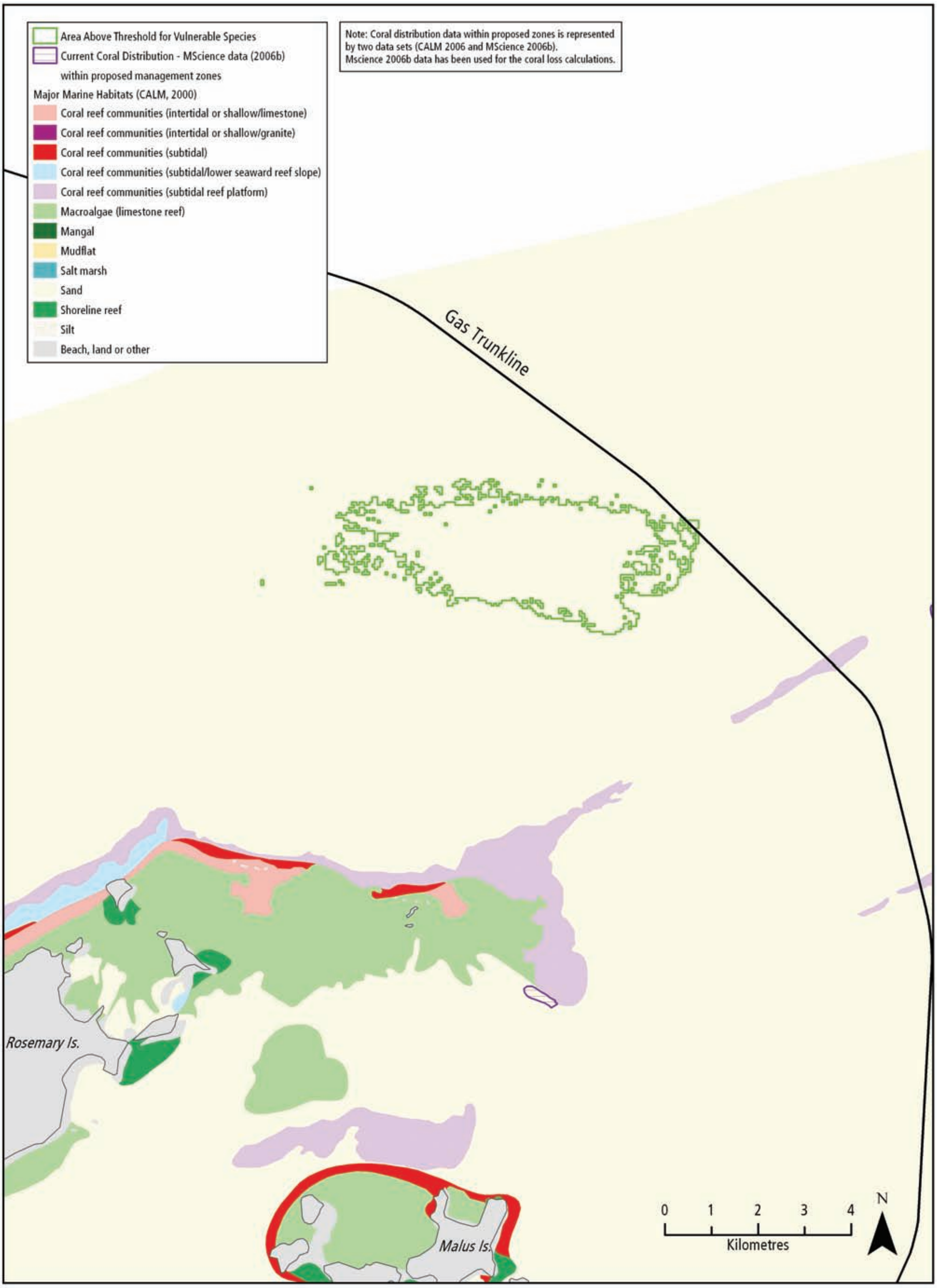


Figure 7-49 Area of Predicted Direct and Potential Indirect Loss of Coral off Holden Point where Sedimentation Rates are Predicted to Exceed Acute Coral Sedimentation Threshold Level for Resilient Species (Winter Season)

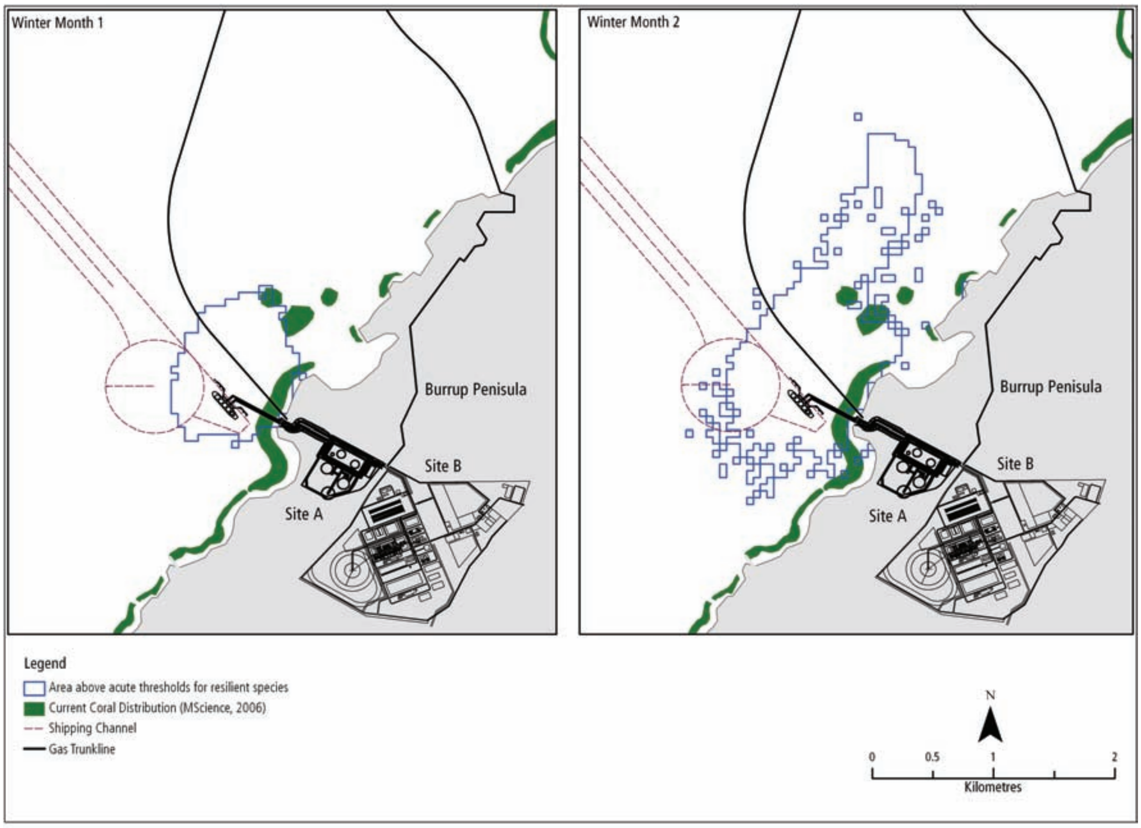


Figure 7-50 Area of Predicted Direct and Potential Indirect Loss of Coral off Holden Point where Sedimentation Rates are Predicted to Exceed Medium Term Coral Sedimentation Threshold Level for Resilient Species (Winter Season)

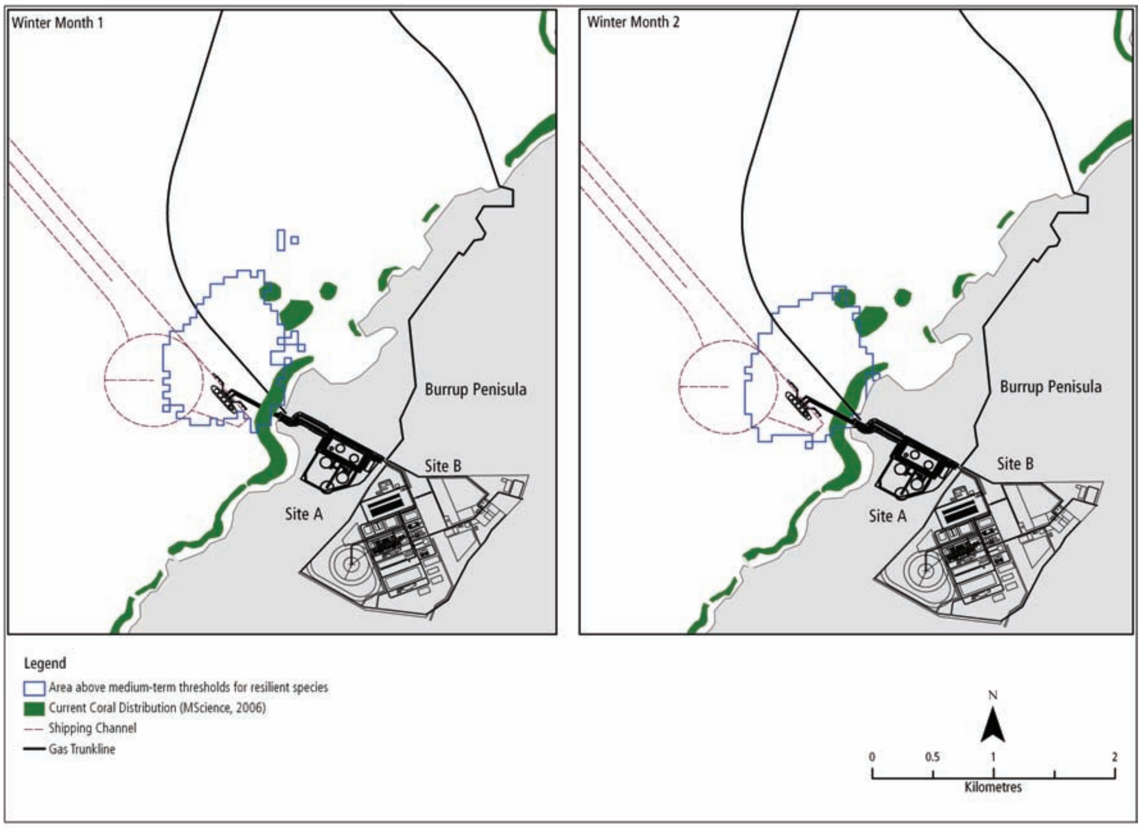


Figure 7-51 Area of Predicted Direct and Potential Indirect Loss of Coral off Holden Point where Sedimentation Rates are Predicted to Exceed Chronic Coral Sedimentation Threshold Level for Resilient Species (Winter Season)

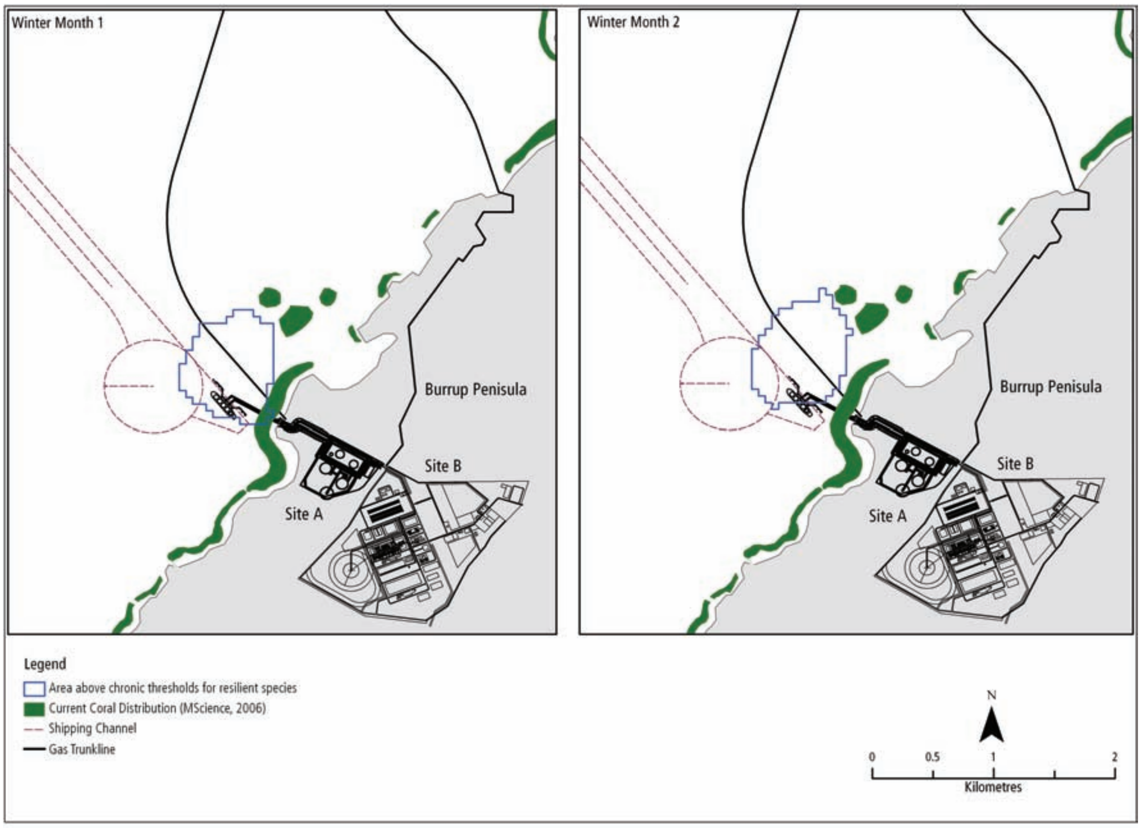


Table 7-34 Comparison between Model Predictions and Previous Monitoring Observations

Predicted Place of Impact	Predicted Model Output – Benthic Primary Producer loss	Previous Dredging Project	Relevant Observations	Reference
Corals at and around Holden Point	Significant losses predicted off Holden Point due to nearshore dredging of navigation channel, turning basin and berth pockets	1986–1987 LNG shipping channel – nearshore dredging and development south of Withnell Bay	Some smothering and mortality of corals nearshore from dredging with an estimated 10% decline in coral cover. Sediments persisted after end of survey. Bleaching and mortality extended 1.3 km from the dredging.	LSC 1989b
		August –September 1989 LNG shipping channel maintenance – 0.15 Mm^3	Sediment layer from LNG shipping channel dredging reduced. Signs of recruitment. No impact from maintenance dredging but many coral communities had been destroyed by cyclones making impact assessment difficult.	LSC 1990
		March 1994 LPG berth pocket dredging – 0.7 Mm^3	Limited cases of mortality attributed to dredging impacts observed at sites within 1.5 km of dredging. No detectable decline in coral cover was observed. Bleaching attributed to high concurrent temperatures.	LDM 1995 URS 2004a APASA and SKM 2006
		Dec 2002–April 2004 Dredging of channel, turning basin and berth pockets at Parker Point	80% coral mortality at one site nearshore to dredge activity due to inundation in sediment mobilised by propeller wash. No other impact from dredging observed.	Blakeway 2005 Stoddart et al. 2005
		Jan – Jun 2004 Bulk Liquids Berth Project. Dredging of channel, turning basin and berth pockets		
		1995–2004 ChEMMS monitoring at 10 sites along western Burrup Peninsula from Holden Point to south Conzinc Bay	Evidence of recovery of corals along the shoreline impacted from previous dredging as described above.	URS 2004a
		2005–2006 LNG Phase V dredging south of Withnell Bay	No significant decline in coral cover on nearshore monitored sites (within 1 km of dredging activities).	MScience 2006a
Corals at Conzinc Island	Increased sedimentation predicted at Conzinc Island, but with some associated losses	1986–1987 LNG shipping channel – spoil disposal into A/B – 6.6 Mm^3	Light sedimentation caused sub-lethal effects and some mortality at Conzinc Island.	LSC 1989b
		Dec 2002–April 2004 Dredging of channel, turning basin and berth pockets at Parker Point	No impacts attributed to spoil disposal activities.	Blakeway 2005; Stoddart et al. 2005
		Jan – Jun 2004 Bulk Liquids Berth Project. Dredging of channel, turning basin and berth pockets		
		2005–2006 LNG Phase V – spoil disposal into A/B – 3.3 Mm^3	Sediment layer observed on coral community but no signs of stress or decline in coral cover were observed.	MScience 2006a

Predicted Place of Impact	Predicted Model Output – Benthic Primary Producer loss	Previous Dredging Project	Relevant Observations	Reference
Corals at Angel Island	Extensive losses predicted at southern tip of Angel Island	1986–1987 LNG shipping channel – spoil disposal into A/B – 6.6 Mm^3	Disposal into A/B caused no mortality at Angel Island as plume dispersed mainly north-south.	LSC 1989b
		Dec 2002–April 2004 Parker Point Upgrade: spoil disposal into spoil ground A/B	No impacts attributed to spoil disposal activities	Blakeway 2005; Stoddart et al. 2005
		Jan – Jun 2004 Bulk Liquids Berth Project spoil disposal into spoil ground A/B – 4.5 Mm^3		
		2005–2006 LNG Phase V – spoil disposal into spoil ground A/B – 3.3 Mm^3	No impact on corals attributable to dredging on the monitored sites on the western side of Angel Island and Gidley Island. However, bleaching and possibly disease may be linked to increased sedimentation, but this is not confirmed.	MScience 2006a
Corals at High Point (top of West Lewis Island)	Possible influence from increased sedimentation associated with disposal into spoil ground A/B	1986–1987 LNG shipping channel – spoil disposal into A/B – 6.6 Mm^3	Sedimentation was not observed to reach Malus Island or islands north off West Lewis Island.	LSC 1989b
		Dec 2002–April 2004 Parker Point Upgrade: spoil disposal into spoil ground A/B	No impacts were observed to the corals as far west as West Lewis Island.	Blakeway 2005; Stoddart et al. 2005
		Jan – Jun 2004 Bulk Liquids Berth Project spoil disposal into spoil ground A/B – 4.5 Mm^3		
		2005–2006 LNG Phase V – spoil disposal into A/B – 3.3 Mm^3		MScience 2006a
Corals off Conzinc, Angel and Gidley islands	No losses expected from trunkline installation through Mermaid Sound	1981–1982 Installation of gas trunkline running alongside Conzinc, Angel and Gidley Islands	Turbidity and sedimentation caused by installation masked by natural variation. Light sedimentation observed on nearby biota (Conzinc, north of Gidley, south of Hamersley Shoal) but no lasting impact.	Meagher and Associates 1984
		Woodside Trunkline System Expansion Project	Turbidity and sedimentation caused by installation masked by natural variation. No indirect impact on corals communities was observed from the dredge plume. Very limited mechanical anchor damage was observed from trunkline installation.	IRCE 2004a IRCE 2004b
Corals at shoal off Rosemary Island	Low level of increased sedimentation predicted but with no losses associated with spoil disposal into deep water site 2B	No relevant observations were found		

Figure 7-52 Historical and Current Distribution of Scleractinian Corals in Management Zones 2-4 including Direct and Indirect Losses due to the Pluto LNG Development

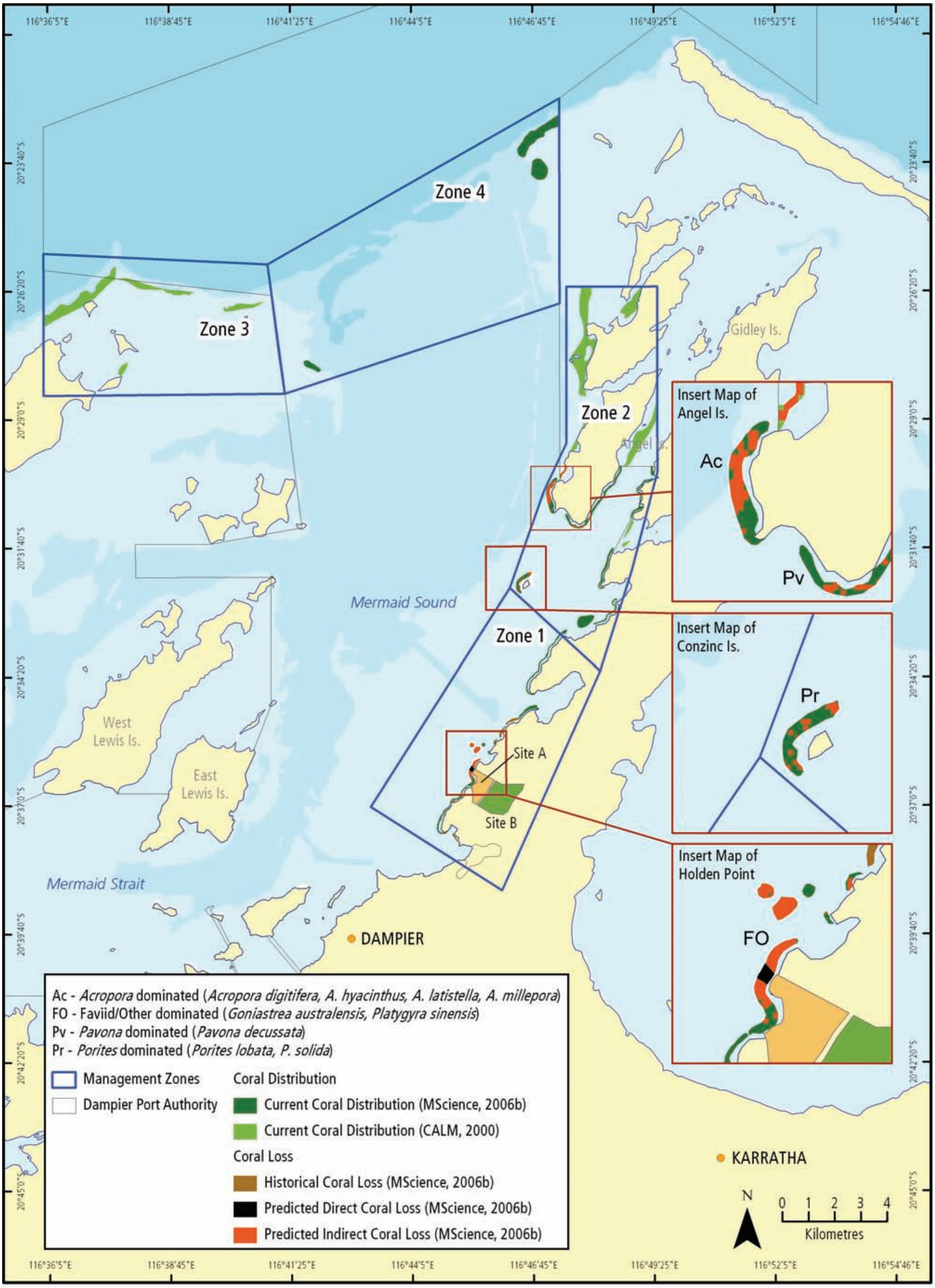


Figure 7-53 Detailed Maps of Predicted Direct and Indirect Losses due to the Pluto LNG Development

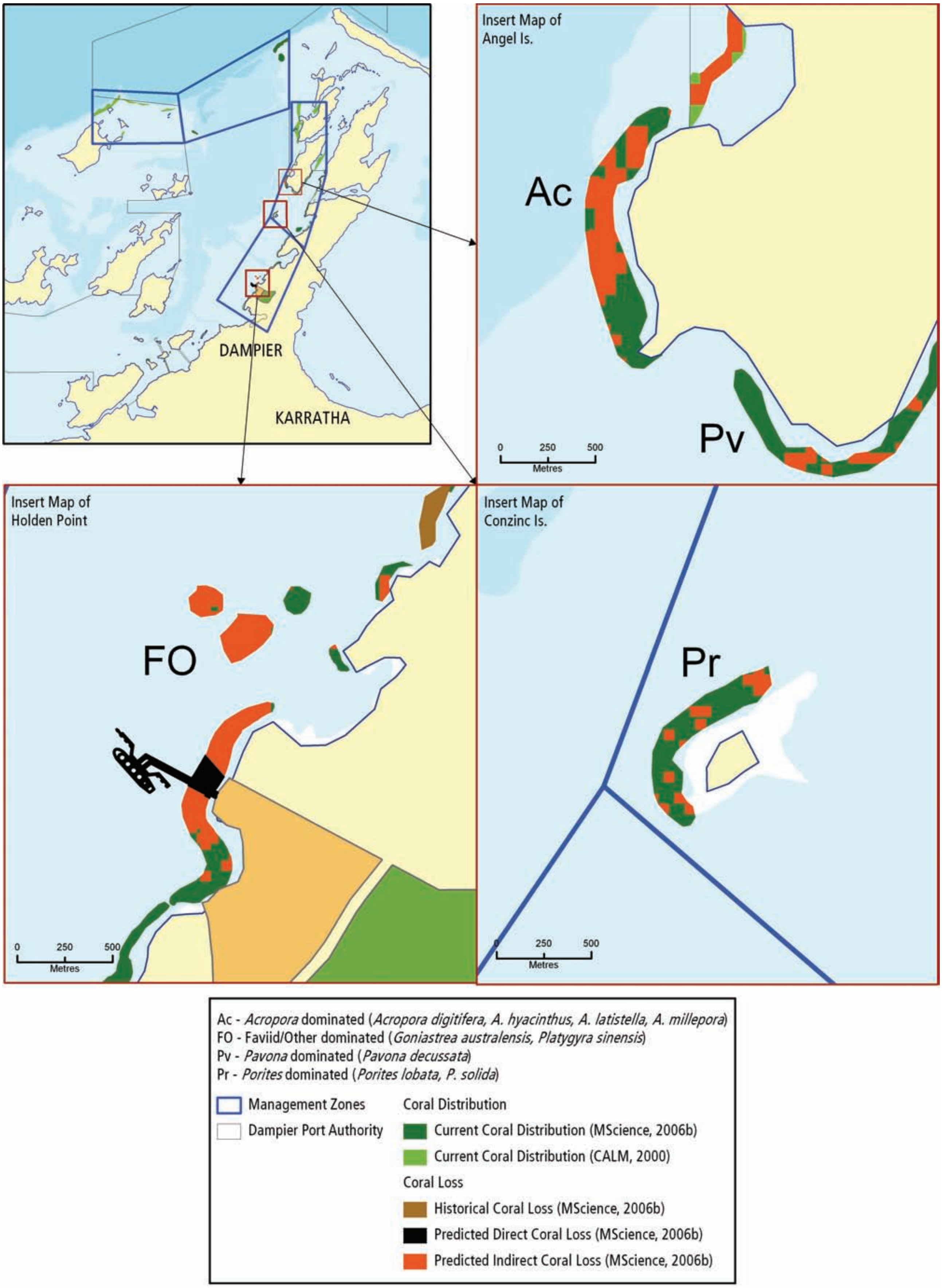


Table 7-35 Predicted Cumulative Coral Loss in Each Management Zone

Management Zone	Management Zone Size	Historical Area of Benthic Primary Producer Habitat [3]	Current Area of Benthic Primary Producer Habitat [3]	Current Historical Loss [3]	Predicted High Impact (Direct Loss) [4]	Potential Medium Impact (Indirect Impact)[1,4]	Predicted Cumulative Impact (Historical Loss + Pluto Direct Impact)	Potential Cumulative Impact (Historical Loss + Pluto Direct and Indirect Impact)	EPA (2004) Loss Threshold
	km^2	m^2	m^2	m^2	m^2	m^2	m^2	m^2	
1	50	737 200	600 400	136 800 (18.6%)	20 000 (2.7%)	156 800 (21.1%)	157 000 (21.3%)	312 600 (42.4%)	0% net loss
2 – MScience data within current DPA limits	51	1 308 300	1 308 300	0	0	188 100 (14.4%)	0	188 100 (14.4%)	1%
2 - CALM data outside current DPA limits		2 936 200	2 936 200	0	0	44.800 (1.5%)	0	44 800 (1.5%)	1%
2 - combined		4 244 500	4 244 500	0	0	232 900 (5.5%)	0	232 900 (5.5%)	1%
3	46	1 892 000	1 892 000	0	0	0	0	0	0%
4	71	1 265 000	1 265 000	0	0	0	0	0	5%

1 Does not include overlapping areas of direct loss
2 Includes colonisation of man-made structure
3 Based on MScience 2006b
4 Based on overlapping loss polygons (Section 7.9.10.4) with area of current coral distribution (MScience 2006b)

7.9.10.6 Chronic Effects of Dredging in Mermaid Sound

Mermaid Sound has been subject to numerous dredging and disposal programmes over the years with a chronic elevation in turbidity and sedimentation levels. The inner harbour in particular has suffered patchy coral losses, both from anthropogenic and natural causes (Blakeway 2005; MScience 2005a, 2005c). Despite this there is evidence that reproduction and recruitment does occur successfully in Mermaid Sound (Stoddart and Gilmour 2005; URS 2004b; LeProvost Environmental Consultants 1991; LSC 1989b), including recovery of previously devastated areas and colonisation of some anthropogenic structures (MScience 2005a, 2006c; URS 2004a). It is not known if the inner harbour communities replenish themselves or depend on an influx of larvae from other areas.

The present day distribution and species composition in the inner harbour can be said to reflect the ability of the Mermaid Sound ecosystem to absorb chronic changes, react and reorganise as described by Nyström and Folke (2001). The majority of surveys have focused on the effects of one dredging operation, which when considered in isolation only has limited impacts in terms of immediate environmental degradation. It is inherently difficult to study long-term effects of chronic or episodic changes.

Mermaid Sound has undergone artificial sediment relocations since the 1960s. There is anecdotal evidence that these episodic dredging activities have caused a gradual rise in turbidity and sedimentation levels, in particular in the inner DPA harbour. While the coral communities in Mermaid Sound appear to be resilient to any gradual changes that may have occurred, it is not known what the limit of this resilience is, and if this limit is being approached. Long-term consequences of chronic changes may be a drop in biodiversity, species distribution, coral cover, and ultimately loss of coral reef habitat (Rogers 1990).

Stressed and bleached corals have been shown to produce gametes inferior in quality and number, or fail to reproduce all together (Mendes and Woodley 2002). For broadcast spawners pelagic fertilisation is negatively influenced by suspended solids (Gilmour 1999), while sedimentation negatively influences larvae settlement (Gilmour 1999; Babcock and Davies 1991; Hodgson 1990) as well as juvenile survival (Babcock and Smith 2000; Sato 1985). Low light regimes after settlement have been shown to negatively influence growth and survival of juvenile corals (Babcock and Mundy 1996).

While sporadic reproductive failures occur naturally without devastating consequences for coral communities, many consecutive failures may severely impact community structure, function and distribution (Tanner et al. 1994). Various dredging programmes over the years have theoretically had the potential to impact on coral reproduction, settlement success and juvenile survival, and thus recovery after degradation both from anthropogenic and natural disturbances (Smith 2006). Consistent reproductive failure may lead to a decline in coral distribution to a level where coral is no longer the dominating benthic primary producer, with a possible shift in dominant life forms and ecosystem function, as described by Done (1992) and McCook et al. (2002). A sedimentation stressed coral reef may typically give way to macroalgae, which invade dead coral structures and compete with coral for space (Nugues and Roberts 2003; McCook et al. 2002). Recovery, if possible, will subsequently depend on influx of larvae from nearby sources, and the availability of suitable substrate for settlement (Nyström and Folke 2001). If algae dominate the substrate it may be difficult for corals to recolonise and the habitat may change permanently from a coral to an algae dominated community.

To better understand the physical environment of the corals in both the inner, mid and outer Mermaid Sound, the Pluto LNG Development is undertaking a baseline survey of sedimentation levels and coral health, as described in **Section 7.9.16**. This continuous collection of sedimentation data and coral cover for nine months prior to the start of the dredging programme will aid in understanding the conditions in which the various coral communities in Mermaid Sound exist, and will also aid in establishing sound trigger levels for sedimentation rates for use in both management of the Pluto LNG Development dredging programme, as well as for future dredge and spoil disposal impact studies. The baseline survey will add valuable information to the current status of the highly variable environment in which the corals of Mermaid Sound exist, and the processes which influence their distribution and survival. This information may also be used in development of environmental quality criteria as part of the EQMF for Mermaid Sound (DoE 2006a).

7.9.11 Effects on Habitat at Deep Water Spoil Disposal Ground 5A

Based on interpretation of preliminary geotechnical data collected along the gas trunkline route, the habitats at the nearby spoil disposal ground 5A are likely to similarly comprise fine to coarse sands with shell fragments with no or little epibenthic fauna. The preliminary geotechnical survey undertaken by Woodside in December 2005 retrieved coral and calcarenite sediments from only two samples in water depths of 20–30 m along the gas trunkline route. Spoil disposal activities into spoil ground 5A could therefore potentially affect coral habitat of limited extent. However, as the majority of spoil ground 5A extends beyond 30 m water depth, this proposed spoil ground is unlikely to support benthic primary producers or other epibenthos. The residual risk of effects to the habitat at spoil ground 5A will depend on the exact species assemblages encountered. A marine baseline environmental survey will be undertaken at spoil disposal ground 5A when the gas trunkline route has been finalised. An assessment of environmental effects will then be undertaken and additional mitigation and management measures will be developed at the time, if considered necessary.

7.9.12 Effects on Seabed Characteristics

Alteration of the seabed characteristics in the immediate vicinity of the dredging footprint of the navigation channel and, to a lesser extent, of the gas trunkline is unavoidable. Sedimentation is likely to change the particle size distribution of receiving sediments, with larger particles tending to settle out closer to the suspension source, with finer particles likely to stay suspended for longer and drift further away prior to settling. The particle size distribution of the upper 1 m seabed in the proposed Pluto LNG Development navigation channel is shown in **Figure 7-6**. The variation in particle size distribution throughout the footprint is large, especially in close proximity to shore, where pockets of both very fine and very coarse sand are found together. The impact by settling particles will therefore vary depending on the receiving sediments. Alteration of seabed characteristics is considered to be a medium residual risk.

7.9.13 Effects on Commonwealth EPBC Act Listed Species

A description of the Commonwealth EPBC Act listed species that may occur within the Development area is presented in **Section 6.3.8**. The majority of these species are likely to occur within the Dampier Archipelago area. **Figure 7-10** presents the distribution of sensitive marine fauna within the vicinity of dredge and dredge spoil disposal grounds.

Impacts to Fish, Marine Reptiles and Marine Mammals: Direct impacts may include temporary disturbance effects associated with the suspension of sediments within the water column. In certain situations this may lead to smothering and/or disorientation of sea turtles, marine mammals, dugongs and other EPBC Act listed species including sea horses and sea snakes, in close proximity to the disposal point. Fish, dolphins and whales are agile and are unlikely to be significantly impacted in this manner. These species are likely to exhibit behavioural responses during disposal operations including avoidance.

Indirect impacts associated with an increase in water turbidity during dredging and dredge spoil disposal operations include effects on the foraging success of marine mammals and sea turtles. However, the potential impact is likely to be relatively minimal given that spoil disposal will be intermittent and the energy spent in relocating to less turbid waters by these animals, will be minimal in the context of their usual activities. The widespread availability of food within the Dampier Archipelago is likely to offset any temporary loss of feeding within the dredge plume area. Furthermore, none of the proposed spoil disposal grounds are located in the immediate vicinity of any known sea turtle or dugong foraging areas or habitat. Sediment plume dispersion modelling indicates that none of the known sea turtle nesting beaches in the Dampier Archipelago will be affected by elevated TSS or sedimentation concentrations during either dredging or dredge spoil disposal activities. The disposal of spoil into the deep water spoil grounds 2B and 5A may potentially impact flatback turtles during inter-nesting and migratory periods. However, the implementation of measures contained within the DSDMP (**Appendix I**) are likely to reduce any residual risks to low.

Spoil ground A /B and northerly extension is located within an area frequented by humpback whale females and their calves during their southerly migration in spring each year. The risk of impacts to humpback whales from dredge spoil disposal during this period is considered medium given that dredge spoil disposal into this ground will coincide with the presence of humpback whales for a period of time. These animals are likely to avoid areas where elevated TSS concentrations will be experienced immediately following spoil disposal events. The implementation of a detailed DSDMP will reduce the risk of disturbance to these species during this sensitive period.

Disposal of spoil into deep water spoil disposal grounds 2B and 5A are unlikely to have significant impacts on whale migration.

Impacts to Seabirds: The Dampier Archipelago represents a nesting area for at least 16 species of seabirds (CALM 2005). A number of the islands and rocks are known breeding grounds for EPBC Act listed species including wedge-tailed shearwaters (*Puffinus pacificus*), Caspian terns (*Sterna caspia*), bridled terns (*Sterna anaethetus*) and roseate terns (*Sterna dougallii*). Potential impacts to seabirds from dredge spoil disposal include temporary disturbance to feeding and diving.

Conzinc Island is a seabird breeding island and is located to the south-west of spoil ground A/B and the proposed northern extension. Following a dredge disposal event, the waters around Conzinc Island are predicted to experience relatively minor increases in TSS concentrations (**Figure 7-35a** and **Figure 7-35b**). Similarly, the islands at the entrance to Mermaid Sound immediately to the south of deep water spoil ground 2B are important seabird breeding islands. Sediment plume dispersion modelling predicts that the waters immediately surrounding these islands are unlikely to experience elevated TSS concentrations during winter disposal operations (**Figure 7-27**). These waters may receive slightly elevated TSS concentrations during summer disposal operations for short periods (that is, days within a month) (**Figure 7-26**). The environmental risk of impacts to seabirds from dredge spoil disposal operations is predicted to be low.

7.9.14 Summary of Predicted Impacts

The effects of historical dredging activities within Mermaid Sound are well documented. In the last 40 years over 20 dredging operations have been undertaken and more recently a number of these operations have been monitored to assess ecological effects from elevated suspended solids and sedimentation concentrations during and immediately after the dredge event.

The simulation of the Pluto LNG Development dredging programme provides an indication of the areas of seabed and habitats that are predicted to be exposed to elevated suspended solids and sedimentation concentrations. The main impacts that are predicted during the dredging programme are the effects of acute sedimentation in the localised vicinity of the dredge activities. Direct coral losses have been estimated at a subtidal coral reef located adjacent to Holden Point from dredging of the trunkline, berth pocket and turning basin. As the dredging moves progressively along the channel and into deeper water, the effects of sedimentation on coral reefs are likely to be reduced to below coral threshold levels. The disposal of spoil into Mermaid Sound spoil ground A/B and a proposed northerly extension to spoil ground A/B is also predicted to result in coral losses at Angel Island and Conzinc Island. No losses are predicted as a result of disposal at deep water spoil ground 2B.

Elevated TSS concentrations from dredging and dredge spoil disposal activities are not predicted to build up over time. The sediment plume dispersion study predicts that TSS concentrations at nearby sensitive receptors are likely to receive pulses of elevated TSS concentrations followed by a return to near background concentrations.

Dredging and dredge spoil disposal activities are also predicted to impact mobile marine fauna including EPBC Act listed species. Other than direct interference of the dredge vessels with marine mammals and sea turtles which is assessed separately in **Section 7.4**, spoil disposal into spoil ground A/B is predicted to result in a moderate level of impact on humpback whales females and calves resting areas during sensitive periods, in terms of elevated TSS and reduction in water quality at this location. Dredging and spoil disposal is not predicted to impact on sea turtle or dugong habitat within Dampier Archipelago.

7.9.15 Preventative and Management Measures

Potential impacts to biota from dredging will be managed in accordance with a detailed DSDMP. This plan will be prepared and submitted to the relevant regulatory agencies for approval prior to dredging commencing. The plan will outline specific mitigation and monitoring measures to limit environmental effects, and will be implemented prior to commencement of dredging activities. The framework DSDMP is provided in **Appendix I**.

The benthic habitat at the deep water spoil grounds (2B and 5A) has been described (**Section 7.9.5**). A further, more detailed marine environmental baseline survey will be undertaken at spoil ground 5A, following determination of the final offshore route.

Management of Indirect Impacts

To minimise indirect impacts (for instance, elevated turbidity and reduced water quality) to sensitive habitats and species (including EPBC Act listed species), certain measures will be implemented prior to, during and post dredging. Examples of management measures that will be considered are presented in **Table 7-36** and include:

- Preventing dredging operations during coral mass spawning events in areas where activities may adversely affect corals or coral larvae settlement.
- Reducing impacts associated with propeller wash, as far as reasonably practicable by targeting dredging of shallow areas to times when the dredge vessel is empty and/or coincide with high tide.
- Utilising favourable weather, tide and current conditions as far as reasonably practicable to limit effects when dredging or disposal in proximity to sensitive areas
- Reducing trailer suction hopper dredge overflow and overflow of barges through operational procedures.
- Disposal of spoil further away from the potential area of impact sites within the spoil areas; taking prevailing weather conditions into consideration to avoid plumes being forced towards sensitive areas.
- Limit anchor and anchor chain interference with coral communities by anchoring outside of the rocky outcrops north of Holden Point.
- Location of spoil grounds away from sensitive areas and utilising previously disturbed spoil grounds as far as possible.
- The dredging method will include disposal of spoil into spoil grounds within Mermaid Sound for the shortest period, practicable.
- The method of dredging and transporting spoil disposal is based on a combination of cutter suction dredging and pick up by trailer suction hopper dredge.
- Disposal of spoil into spoil ground A/B and a northerly extension of this area will be restricted to a relatively small defined area within the overall limits of this area. This will minimise turbidity levels to a small area as opposed to disposal throughout spoil ground A/B.
- The majority of spoil will be disposed into an offshore spoil ground located outside of Dampier Port. This will minimise elevated turbidity levels experienced at sensitive coral habitat and other benthic habitats within the Dampier Archipelago, as well as at turtle or dugong aggregation or feeding areas.

Management of Direct Impacts

Direct impacts to seabed habitats will occur during the construction of the navigation channel, and the trunkline landfall. Disturbances to coral habitat will be confined to a 10 m buffer zone around the jetty and causeway footprint.

Mitigation and management measures for the protection of marine mammals and sea turtles in relation dredging and dredge spoil disposal activities include:

- Prior to commencement of dredging activities, the dredging contractor and crew will receive an induction that, among other things, describes the location of sensitive marine mammal and sea turtle habitat in relation to proposed dredging activities and seasonal environmental sensitivities, such as the humpback whale migration and coral spawning events.

- The use of sea turtle deflection devices will be considered for use on trailer suction hopper dredges (note that these devices are not considered feasible for application to cutter suction dredges). An alternative to turtle deflectors which will also be considered are jetting systems. These systems force water and marine fauna (in particular sea turtles) away from the drag head, thereby avoiding any direct contact. Upon commencement of dredging, the jetting system will be switched on, prior to engaging the dredge pumps. When the dredging operation stops, the dredging pumps will be switched off prior to switching off the jetting system.
- Prior to commencement of sea disposal activities, the dredging contractor will check for the presence of marine mammals and sea turtles within 300 m radius of the dredge vessel.
- Disposal activities may only commence if no marine mammals or sea turtles have been observed within 300 m of the dredge vessel for ten minutes immediately preceding commencement of disposal operations.
- Should any marine mammals or sea turtles be observed within 300 m of the vessel prior to and during disposal activities, disposal activities must stop and may not recommence until:
  - the animal/s are seen to move >300 m from the vessel
  - the animals have not been seen for >20 minutes duration or
  - the vessel moves to a location >300 m from the observed animals.
- The dredging contractor will document any incidents that occur during disposal operations that result in injury or mortality of marine mammals or sea turtles. Details of the incident including time and date of incident, cause of injury/mortality and the species (if known) will be recorded and reported to the DEC and the DEH.
- Sightings of marine mammals and sea turtles will be maintained in the vessels daily log book.

Monitoring programmes designed to detect direct and indirect impacts will also be developed and are discussed in **Section 7.9.16**.

7.9.16 Monitoring Programmes

The DSDMP will be supported by a suite of monitoring programmes including:

- baseline pre-dredge study on sedimentation regimes and coral health
- predictive forecast modelling using real-time weather and current conditions
- monitoring of physical and biological indicators (reactive management)
- post-dredge baseline study of coral health to determine delayed effects.

Baseline Study: The evaluation of environmental impacts has identified acute sedimentation as the main cause of mortality of coral communities close to the dredge and dredge spoil disposal activities. Though chronic effects such as lower but continuous sedimentation and light attenuation are thought to have less detrimental effects they still have the potential to impact negatively on the benthic communities in Mermaid Sound. Prior to dredging commencing in 2007, an extensive baseline survey will investigate sedimentation rates continuously for nine months using a newly developed sedimentation logger (Thomas and Ridd 2005). The proposed loggers have the capability to measure instantaneous sedimentation during time intervals of 10 minutes. A number of loggers will be installed at sites within and outside Mermaid Sound. The data from this monitoring will be useful in determining the conditions under which coral communities are able to comfortably exist and will represent a reliable basis on which to develop suitable 'trigger levels' for use in the management monitoring. This approach has been explored previously by McArthur et al. (2002) and is currently implemented in management of dredging in the Great Barrier Reef Marine Park in Queensland. The sediment loggers will be used throughout the dredging programme as a reactive monitoring tool for early warning of deterioration in sedimentation regimes. Data from this monitoring programme will be used in development of environmental quality criteria as part of the EQMF for Mermaid Sound (DoE 2006a).

Predictive Forecasts: The nature of acute sedimentation means it will happen quickly and without prior warning signs therefore limiting the effectiveness of reactive response management. Reactive monitoring will therefore not be capable of preventing loss of coral habitat caused by acute sedimentation. To identify coral habitat that is at high risk of receiving acute sedimentation a predictive model will be run on real-time weather and current conditions to predict the spread of the dredge plume and associated sedimentation on a day-by-day basis. This will allow measures to be implemented on days where modelling indicates high likelihood of impact to sensitive receptors and to some extent, enable planning of the daily dredging programme to minimise impact.

The continuous collection of sedimentation data during the baseline study will enable 'ground-truthing' and fine-tuning of the model prediction, including an assessment of the model accuracy. This will increase the ability of the model to determine when predicted impacts may exceed threshold values and when to react to exceedances in a timely manner. This will include maintaining TSS concentrations below set threshold levels in close proximity to the Dampier Salt intake.

Monitoring of Physical and Biological Indicators: The aim of the monitoring programme is to provide early detection of physical stressors (sedimentation and turbidity) and biological indicators (corals) that can be used for active management to avoid or minimise potential environmental impacts associated with the dredging programme.

Monitoring of sedimentation and turbidity on a real-time basis provides an early indication of potential stressors that may result in biological impacts, as such they are referred to as a 'lead indicator'. Monitoring of coral health parameters and coral mortality provides a measure of impact after the event and these are referred to as 'lag indicators'.

It is proposed to utilise a combination of lead and lag indicators to monitor and where necessary respond to, impacts of the dredge programme.

The coral monitoring sites will consist of 'impact sites' within the management zones described in **Section 7.9.10.4** and 'reference sites' outside of the zone of impact. The majority of these sites have a history of prior monitoring (Stoddart and Anstee 2005), with new sites established only where no previous sites are available in the areas where monitoring is necessary.

Reactive Management: The reactive management is based on a tiered response to a combination of lead and lag indicators and takes consideration of:

- frequency of potential disturbance
- reversibility of stressor, that is how successful intervention measures would be in preventing biological impact
- natural variability.

The threshold values (also known as trigger values) for lead indicators, sedimentation and turbidity, are to be based on the results of baseline monitoring at the sites.

The first tier trigger value (T1) is when measured conditions exceed the 95th percentile of all records of natural variability for the season at that location. The second tier trigger value (T2) is when measured conditions exceed the 99th percentile of all records of natural variability for the season at that location.

An element of duration and/or recurrence will be included in the trigger values as this will allow for response to repetitive stressors, for example, not to exceed the 95th percentile for more than five days within any 30 day period. However, it will be necessary to view the baseline dataset in order to determine the most meaningful value.

The threshold values for lag indicators, coral health and mortality, will also be based on the results of baseline monitoring at reference and impact sites. Tier 1 trigger value for lag indicators are when the net loss is equal or greater than 10% and Tier 1 trigger value for lag indicators are when the net loss is equal or greater than 20%.

Reporting: Reporting of monitoring findings including exceedence of trigger levels and implementation of management measures, will be communicated in a timely manner and on an ongoing basis to the relevant regulatory agencies throughout the dredging programme. Reporting for the pre-dredge survey will include a comparison against findings from the baseline survey.

7.9.17 Residual Risks

Residual risks will be reduced through the implementation of the preventative and management measures outlined previously. Residual environmental risks will remain during the dredging operations and post-dredging. The significance of the residual risk will depend, in part on the success of the management measures and coral monitoring programme, the exact timing of the dredging operations and the sensitivity of environmental receptors. Indirect residual risks that are likely to persist either during or post-dredging and dredge spoil disposal operations include:

- Loss of coral from removal of habitat at Holden Point for the construction of a causeway / jetty. The recovery of the deteriorated coral habitat at Holden Point impacted by acute sedimentation might take years, if full recovery is possible.
- Contribution to the chronic elevation in turbidity and sedimentation rates in Mermaid Sound with associated effects on benthic primary producer habitat.
- Disturbance to humpback whale female and calves resting area within Mermaid Sound.

The predicted residual impacts are presented in **Table 7-36** and are anticipated to vary between different habitats and species. Direct residual risks associated with the removal of benthic habitat are described in **Section 7.5**.

Table 7-36 Summary of Impacts, Management and Risks of Dredging and Dredge Spoil Disposal

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Suspended solids (TSS)	Dredging and spoil disposal	Reduction in light availability to benthic primary producer habitats in Dampier Archipelago	A detailed DSDMP will be developed and implemented (**Appendix I**). This plan will be submitted to the DEH and DEC for approval prior to dredging commencing. Management measures that will be considered include: • Reducing impacts associated with propeller wash, as far as reasonably practicable by targeting dredging of shallow areas to times when the dredge vessel is empty and/or coincide with high tide. • Utilising favourable weather, tide and current conditions as far as reasonably practicable to limit effects when dredging or disposal in proximity to sensitive areas. • Reducing trailer suction hopper dredge overflow and overflow of barges through operational procedures. • Disposal of spoil further away from the potential area of impact sites within the spoil areas; taking prevailing weather conditions into consideration to avoid plumes being forced towards sensitive areas. • Limit anchor and anchor chain interference with coral communities by anchoring outside rocky outcrops north of Holden Point. • Preventing dredging operations during coral mass spawning events in areas where activities may adversely affect corals or coral larvae settlement. • Location of spoil grounds away from sensitive areas and utilising previously disturbed spoil grounds as far as possible. • The dredging method will include disposal of spoil into spoil grounds within Mermaid Sound for the shortest period, practicable. • The method of dredging and transporting spoil disposal is based on a combination of cutter suction dredging and pick up by trailer suction hopper dredge. • Disposal of spoil into spoil ground A/B and a northerly extension of this area will be restricted to a relatively small defined area within the overall limits of this area. This will minimise turbidity levels to a small area as opposed to disposal throughout spoil ground A/B.	C	4	H
		Reduction in light availability to sponge community habitat in Dampier Archipelago		C	2	M
		Reduction in light availability to other benthic biota in Dampier Archipelago		D	3	M
		Disturbance to fish		E	2	L
		Disturbance to sea turtle foraging and nesting areas		E	2	L
		Disturbance to seabirds		E	2	L
		Disturbance to marine mammals		E	2	L
		Disturbance to humpback whale female and calves resting area		C	2	M
		Reduction in light availability to biota at deep water spoil ground (2B and 5A)		E	2	L
		Water quality		C	4	H

<table>
<tr><th rowspan="2">Aspect</th><th rowspan="2">Activity, Event or Source</th><th rowspan="2">Affected Environment or Impact</th><th rowspan="2">Mitigation/Control Measure</th><th colspan="3">Residual Risk</th></tr>
<tr><th>C</th><th>L</th><th>RR</th></tr>
<tr><td>Sedimentation</td><td>Dredging and spoil disposal</td><td>Smothering effects leading to stress and mortality of benthic primary producer habitats</td><td rowspan="7">• The majority of spoil will be disposed into an offshore spoil ground located outside of DPA limits. This will minimise elevated turbidity levels experienced at sensitive coral habitat and other benthic habitats within the Dampier Archipelago.
• Should any marine mammals or sea turtles be observed within 300 m of a vessel during dredging spoil disposal activities, disposal must be stopped and may not recommence until the animal/s are seen to move >300 m from the vessel or have not been spotted for >20 minutes.
• The dredging contractor will document any incidents that occur during disposal operations that result in injury or mortality of marine mammals or sea turtles. Details of the incident including time and date of incident, cause of injury/ mortality and the species (if known) will be recorded and reported to the DEC.
• Sightings of marine mammals and sea turtles will be maintained in the vessels daily log book.
• Identifying opportunities for recycling dredge spoil material as far as reasonably practicable at the time of dredging.
The DSDMP will be supported by a suite of monitoring programmes including:
• baseline pre-dredge survey
• predictive forecasts
• monitoring of 'lead' indicators
• monitoring of 'lag' indicators
• post-dredging survey of long term effects
• monitoring of communication and reporting.</td><td>B</td><td>3</td><td>H</td></tr>
<tr><td></td><td></td><td>Smothering effects leading to stress and mortality of sponge communities</td><td>C</td><td>3</td><td>M</td></tr>
<tr><td></td><td></td><td>Smothering effects leading to stress and mortality of other benthic habitats</td><td>D</td><td>3</td><td>M</td></tr>
<tr><td></td><td></td><td>Smothering of EPBC Act listed species</td><td>D</td><td>1</td><td>L</td></tr>
<tr><td></td><td></td><td>Smothering effects on benthic habitats at deep water spoil grounds (2B and 5A)</td><td>D</td><td>5</td><td>M</td></tr>
<tr><td></td><td></td><td>Alteration of surrounding sediment characteristics</td><td>D</td><td>5</td><td>M</td></tr>
<tr><td>Contamination</td><td>Dredging and spoil disposal</td><td>TBT effects to marine biota</td><td>1</td><td>D</td><td>L</td></tr>
</table>

7.10 Hydrocarbon Spills

7.10.1 Considerations

This section describes the potential accidental hydrocarbon spill events associated with the Pluto LNG Development, the likelihood of their occurrence, and the environmental resources that may be affected in the event of a spill. This section also describes the measures that will be implemented to prevent spills from occurring, and to respond in the event that they do occur.

Woodside has conducted a series of multi-disciplinary workshops and reviews to firstly identify credible potential hydrocarbon release scenarios (referred to as 'the event'), and then to estimate the likelihood of spill events occurring (referred to as the primary risk or 'P_1'). Credible spill scenarios identified in the risk assessment were then selected for spill modelling and the results of the modelling were used to determine the secondary risk ('P_2' risk), that is, the probability of hydrocarbons, if spilled, reaching a particular location. Secondary risk is influenced by a range of factors, including the weathering characteristics of the hydrocarbons, the distance of the release location from sensitive receptors, the prevailing weather and tidal conditions and the effectiveness of mitigation measures.

The tertiary risk ('P_3' risk) is then described, and relates to the predicted direct or indirect impacts resulting from a hydrocarbon spill on an identified environmental resource. This risk also considers the temporal nature of the impact, that is, whether the spill is likely to culminate in prolonged or short-term ecological effects to marine species and habitats.

The section concludes by presenting the response measures that Woodside proposes for managing potential hydrocarbon spill events. The process applied to assess the potential environmental effects associated with hydrocarbon spills is outlined in **Figure 7-54**.

7.10.2 Hydrocarbon Characterisation

The following section describes the composition of the two hydrocarbons considered in this assessment, namely condensate and marine diesel.

Pluto Condensate: Pluto condensate is a light hydrocarbon with an American Petroleum Institute (API) gravity of 60.8° and a density of 736.5 kg/m^3. The condensate is composed mainly of short-chained hydrocarbons and 95% of the components have high to moderate volatility at typical atmospheric conditions on the North West Shelf. An analysis of samples taken during the drilling of an appraisal well at the Pluto gas field in April 2005 (Pluto-1) indicates that the condensate has a low concentration of aromatic hydrocarbons (0.84% by volume).

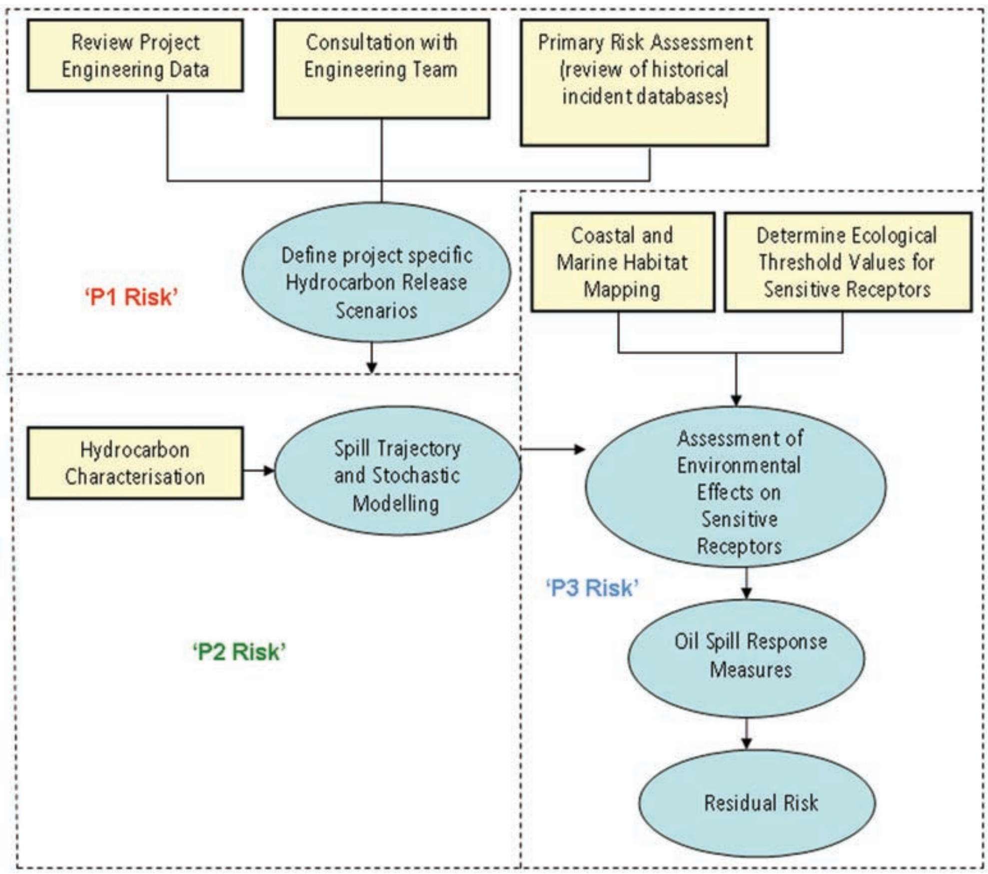
The rate of condensate evaporation will depend on a number of factors, most importantly the release depth within the water column. Predicted weathering of Pluto condensate is presented in **Figure 7-55** which indicates that over 60% of the condensate will evaporate within one hour of sea surface release. Following this period of initial evaporation of the lighter hydrocarbon fractions, the condensate weathering process slows, and approximately 30% of the mass is predicted to remain in the water column as droplets after five days. The predicted weathering characteristics for Pluto condensate were fed into a hydrocarbon spill fate and trajectory model to give a realistic interpretation of the behaviour of Pluto condensate in the ocean (refer to **Section 7.10.4**).

Weathering rates can be significantly slowed in circumstances where condensate is entrained within the water column as fine oil droplets, as will occur from subsea surface releases or due to the rapid churning of water caused by breaking waves.

In the case of a pressurised subsea release, condensate will be atomised into droplets of varying size and diameter. The larger droplets will surface rapidly, but droplets will rise at exponentially slower rates with decreasing diameter, due to resistance from turbulence and density layers within the water column, and entrained droplets will surface over an extended period.

Figure 7-56 presents the predicted weathering for Pluto condensate, if released at a water depth of 600 m with light surface winds. Under these conditions, surfacing rates and hence evaporation rates are shown to be initially rapid, followed by a decrease over time, with approximately 30% of the condensate being predicted to remain in the water column as fine droplets after five days. The prevailing wind conditions will also influence the fate and behaviour of condensate, and under the same subsea release scenario (600 m water depth) with increased wind speeds generating breaking waves at

Figure 7-54 Hydrocarbon Spill Environmental Assessment Process



the surface, a lower percentage of condensate is predicted to evaporate (**Figure 7-57**).

Diesel: Marine diesel is a light hydrocarbon comprised of volatile and persistent hydrocarbons. Depending on prevailing wind conditions, approximately 60–80% by mass of diesel is predicted to evaporate, with the residual mass anticipated to persist for an extended period. The heavier components of diesel have a strong tendency to physically entrain in the upper layers of the water column as oil droplets in the presence of waves. They can however, re-float to the surface in the event that wave energies abate (**Figure 7-58**).

Figure 7-55 Predicted Weathering of Pluto Condensate from Surface Releases

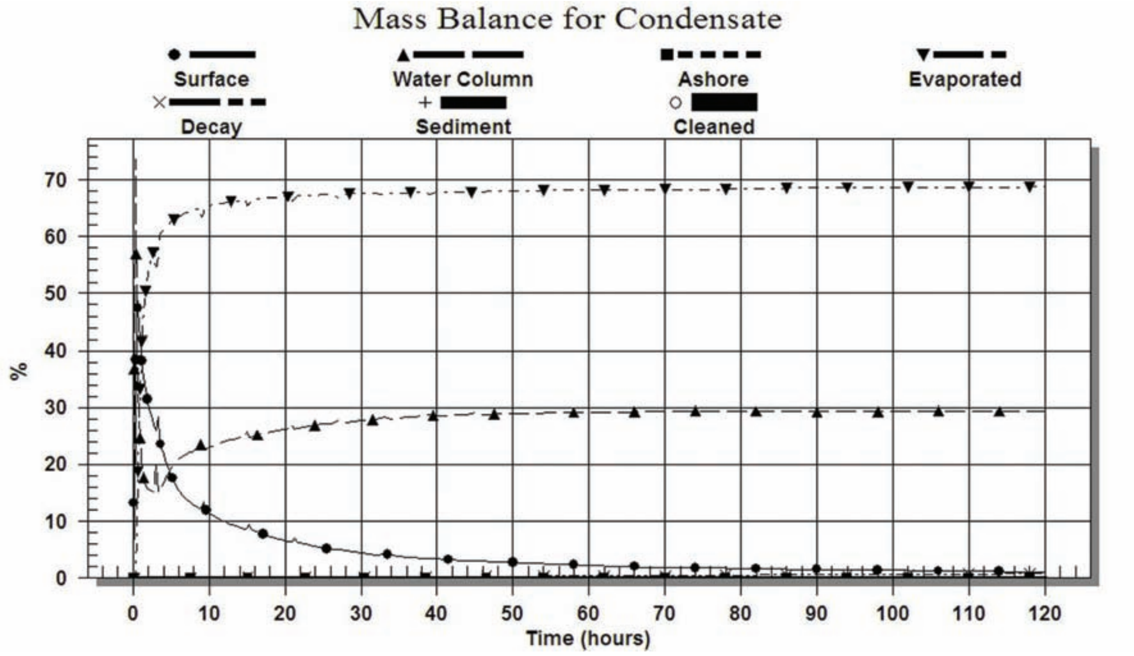


Figure 7-56 Predicted Weathering of Pluto Condensate from Subsea Releases at 600 m Water Depth Under Light Wind Conditions

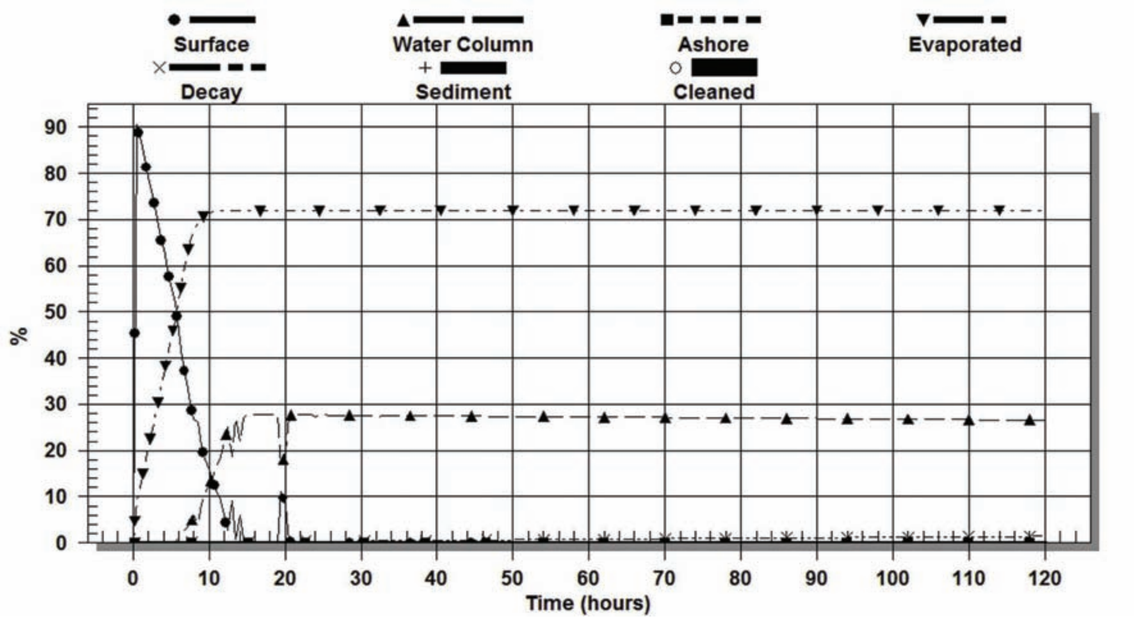


Figure 7-57 Predicted Weathering of Pluto Condensate from Subsea Release at 600 m Water Depth Under Increased Wind Conditions

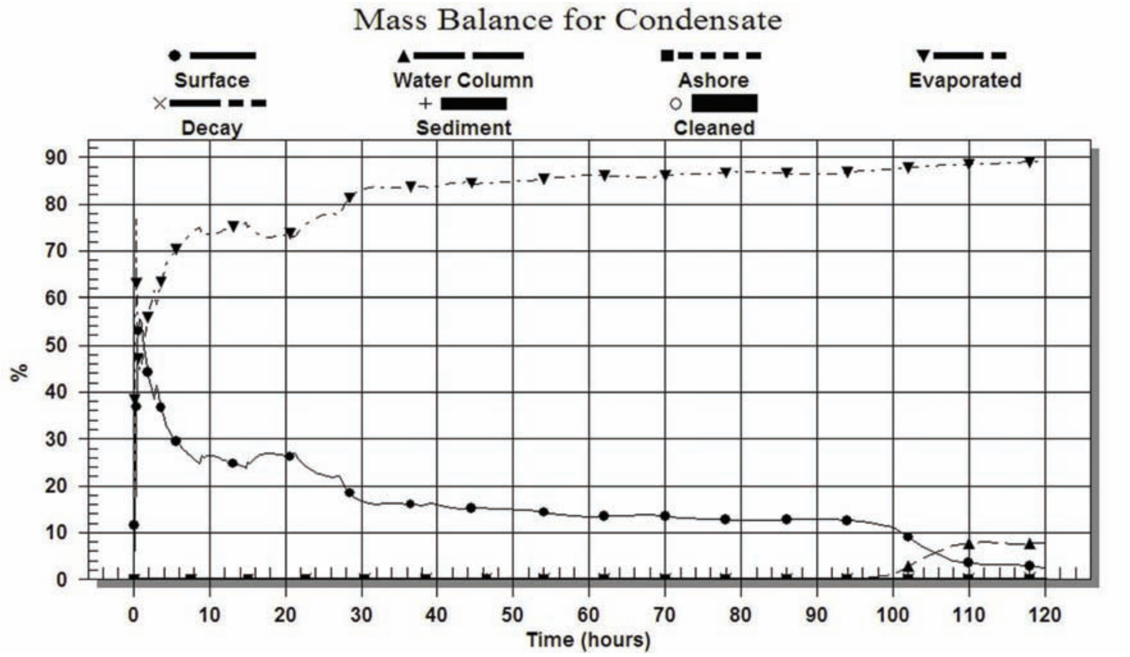
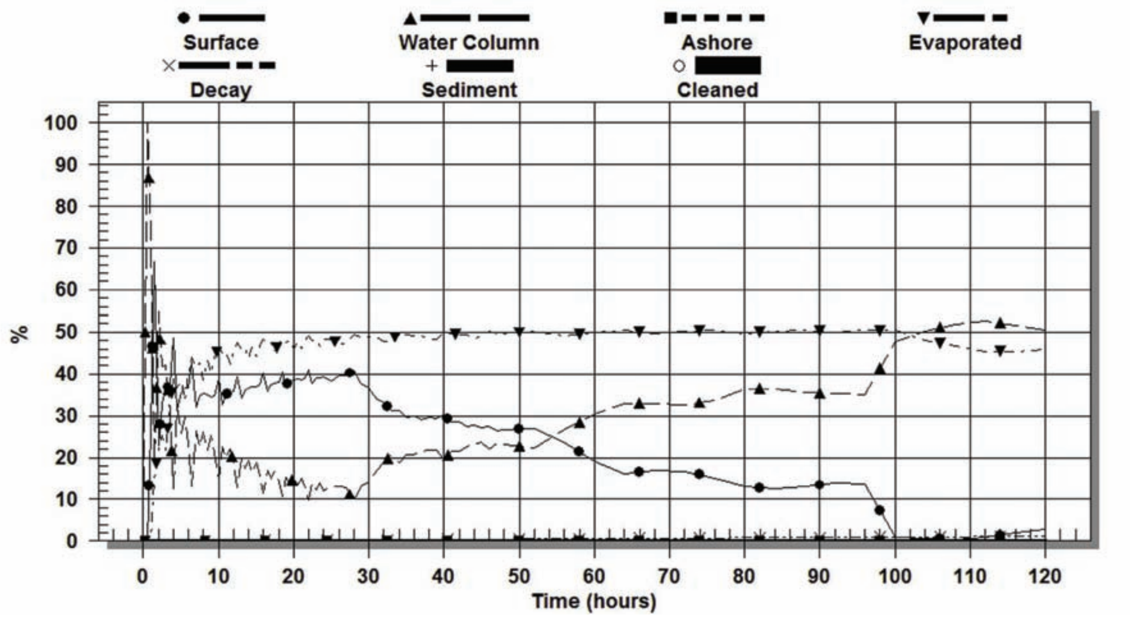


Figure 7-58 Predicted Weathering of Diesel Released onto the Water Surface Under Light Wind Conditions



7.10.3 Primary Risk of Credible Hydrocarbon Release Scenarios

An initial list of 20 possible spill event scenarios was developed following a multi-disciplinary workshop held to validate scenarios and to filter out those events that represented a very low or remote probability of occurrence and/or potential environmental consequence(s). This was a subjective process based on the collective professional experience of the workshop attendees. The outputs from the workshop reduced the number of spill events to those that were considered to represent worst case scenarios in terms of anticipated environmental consequences and frequency of occurrence.

A Marine Spill Primary Risk Assessment was undertaken to determine the risk of a spill event occurring ('P_1' risk) and likely volumes (ERS 2006). In determining the primary risk for the spill scenarios, reference was made to data that is available in the public domain, the majority of which is based on incident history for North Sea and European operations, namely the United Kingdom's Health and Safety Executive records data for North Sea offshore facilities (ERS 2006). It is noted that the source of the data used in the Primary Risk Assessment (North Sea / European waters) reflects operations occurring in an area where there are a number of large facilities with associated support infrastructure in the form of pipelines and support vessels, and where weather conditions are more severe. The Pluto LNG Development is remotely located when compared to the source data, with significantly fewer vessels, pipelines and facilities and a lower presence of third parties (for instance commercial shipping and fishing vessels), that could affect the Pluto LNG Development facilities. Although the data is applicable, the results in terms of primary risk for the Development therefore represent a conservative approach.

The primary risks for the scenarios presented in this assessment are outlined in **Table 7-37**. The risk of a trunkline rupture within Mermaid Sound is unlikely, given that the gas trunkline will be trenched and protected by concrete coating. Furthermore, there has never been any previous disturbance or external impacts to existing trunklines in the vicinity of the Dampier Archipelago.

Well blow-out scenarios were not considered as part of the marine spill primary risk assessment, as the large number of preventative measures in place creates an extremely low likelihood of a blow-out event occurring.

7.10.4 Hydrocarbon Spill Fate and Trajectory Modelling

Woodside commissioned Asia Pacific Applied Science Associates (APASA) to undertake hydrocarbon spill modelling for the Pluto LNG Development (APASA 2006b). The modelling was carried out using the three-dimensional hydrocarbon spill model, SIMAP (Spill Impact Mapping and Assessment Programme). SIMAP is an evolution of the USEPA Natural Resource Damage Assessment Model (French et al. 1996; French 1998 and French et al. 1999) and is designed to simulate the fate and effects of spilled hydrocarbons for both the surface slicks and the three-dimensional plume that is generated in the water column.

Summary of SIMAP (Spill Impact Mapping and Assessment Programme): The SIMAP physical fates model calculates the transport, spreading, entrainment, evaporation and decay of spilled hydrocarbons over time, based on the physical properties of a defined hydrocarbon type and the prevailing weather conditions. The model calculates ocean and slick movement from meteorological and oceanographic data. The operating parameters used by SIMAP included:

- Current data and tidal circulation: APASA's hydrodynamic model, HYDROMAP is an ocean/coastal circulation model that simulates the flow of ocean currents within a model region due to forcing by astronomical tides, wind stress and bottom friction.

Table 7-37 Primary Risk Summary for Potential Hydrocarbon Spill Events

Description	Development Phase	Primary Risk
Flowline rupture at the Pluto gas field	Production (offshore)	2.0×10^{-5} pa
Catastrophic rupture of the gas trunkline (Montebello Islands)	Production (offshore)	8.2×10^{-6} pa
Catastrophic rupture of the gas trunkline (Mermaid Sound/ Holden Point)	Production (nearshore)	8.2×10^{-6} pa
Catastrophic rupture of the gas trunkline (Mermaid Sound/off Gidley Island)	Production (nearshore)	8.2×10^{-6} pa
Leak of gas trunkline (Montebello Islands)	Production (offshore)	1.7×10^{-5} pa
Refuelling accident nearshore from fuel bunker vessel to dredge barge	Construction (nearshore)	4.1×10^{-2} pa*
Major Failure of the condensate load-out line while pressurised (during loading) – dry break coupling fails	Production (nearshore – jetty location)	4.9×10^{-5} pa
Failure of the condensate load-out line while pressurised (during loading) – dry break coupling activated	Production (nearshore – jetty location)	1.6×10^{-2} pa
Leak of condensate line to export jetty (full content of the line)	Production (nearshore – jetty location)	1.4×10^{-2} pa
Grounded export condensate tanker and hull rupture in Mermaid Sound	Production (nearshore)	4.8×10^{-7} pa
Grounded export LNG tanker and hull rupture in Mermaid Sound	Production (nearshore)	5.8×10^{-4} pa

** This scenario is applicable for the period during dredging.*

- Wind data (offshore): Modelled wind data were available for the wider study area from the output of a numerical atmospheric model.
- Wind data (nearshore): Measurements of wind speed and direction have been made at a number of stations within the region by the Australian Bureau of Meteorology, with the most extensive available archive being from Karratha Airport (1993 to present). An archive of wind measurement was also available for a site on Legendre Island, at the northernmost end of the Dampier Archipelago, which provided a suitable source of wind data to represent conditions further offshore. However, this data spanned one year only (1997).

Input specifications for oil-types include the density, viscosity, pour-point, distillation curve (volume lost versus temperature) and the aromatic/aliphatic component ratios within given boiling point ranges. These algorithms are used to proportion the distribution of the oil (as mass and concentrations) over time into the following components:

- surface bound oil
- entrained oil (non-dissolved oil droplets that are physically entrained by wave action)
- dissolved hydrocarbons (principally the aromatic and short-chained aliphatic compounds)
- evaporated hydrocarbons
- sedimented hydrocarbons
- decayed hydrocarbons.

The SIMAP trajectory model separately calculates the transport of the material that is on the water surface (as surface slicks), in the water column (as either entrained whole oil droplets or dissolved hydrocarbon), that has stranded on shorelines or has settled out of the water column onto the seabed. For subsea releases, a blow-out module is used. The blow-out algorithms calculate the loss of soluble components to the water column taking into account the depth of release and the size of oil parcels that are produced under different conditions.

Stochastic Modelling: Risks of exposure from each spill scenario were determined following a stochastic modelling procedure. Stochastic modelling predicts the most probable path and transport rates for released hydrocarbons and also predicts a time for the fastest transport of hydrocarbons to reach the shoreline.

Randomly selected weekly samples of wind and current data were applied to simulate multiple spills under each scenario, with environmental forcing data stratified by major seasons.

Seasonal analysis was undertaken of offshore wind datasets applied to the modelling including the NCEP/NCAR numerical atmospheric model created by the NOAA-CIRES Climate Diagnostic Center, (Colorado, USA) and also wind data from the North Rankin A platform between 1993 and 2000. This analysis indicated that winds over the open shelf are predominately from the south-west during summer (September to March) and from the east and south-east during winter (May to July). Wind directions and speeds are more variable and frequent from the south during April and August. Wind data used to simulate inshore spill scenarios within the Dampier Archipelago included Bureau of Meteorology data for Karratha Airport (1993–present) and data from Legendre Island (1997). This data exhibited similar seasonal patterns to the offshore datasets. The spill simulations were thus carried out using wind data from three major wind seasons:

- summer months (September to March)
- winter months (May to July)
- transitional months (April and August).

Because wind and current conditions were randomly selected, each simulated spill followed a different path and displayed a different weathering history. It should be noted that because metocean conditions varied within and among the three sample periods, the trajectories and distances travelled also varied among individual simulations. The trajectory and fate of spilled material was modelled during 100 independent simulations of each combination of spill scenario and season. Each figure presented in this section combines these 100 different spill events and determines the combined probable area within which the spill may be found. The spill envelopes therefore do not represent the extent of any one spill event, but instead represent a worst case scenario in terms of potential fate and effects. Each simulation covered a period of five days after the cessation of each spill.

The results of all simulations were summarised as exposure contours in terms of the frequency of contact and the minimum elapsed time before contact for each 50 m x 50 m area of the water surface surrounding the spill source.

Model Threshold Values: Threshold levels have been applied to the various model outputs and include:

- Probability of surface hydrocarbon exposure (%): A threshold level of 0.001 mm slick thickness has been applied for surface spill exposure. This thickness is equivalent to condensate loading of approximately 0.7 mg/m^2 which is the limit at which the condensate or diesel will be visible (NOAA HAZMAT 1997).
- Minimum time before hydrocarbon exposure (hours): A threshold time of five days following cessation of the spill was applied to the model, providing for complete weathering to the defined threshold, corresponding to the surface slick threshold of 0.001 mm.
- Highest (worst case) instantaneous concentration of entrained hydrocarbons from condensate spills (ppm): A threshold level of 1 ppm (that is, 1000 ppb) has been selected based on the reported range of condensate toxicity concentrations 0.5 to 4 ppm over 24 or 96 hour exposure periods.

7.10.5 Modelled Scenarios

The spill scenarios that are presented within this section represent credible scenarios, which have a primary risk greater than 1 in 10 000, and include:

- leakage of the gas trunkline in Mermaid Sound (a small sized spill) P_1 Risk = 1.7 x 10^{-5} pa
- failure of the condensate load-out pipeline during the loading of an export tanker in Mermaid Sound – dry couplings fail (a medium sized spill) P_1 Risk = 4.9 x 10^{-5} pa
- failure of the condensate load-out pipeline during the loading of an export tanker in Mermaid Sound – dry couplings activated (a small sized spill) P1 Risk = 1.6 x 10^{-2} pa
- an operational diesel refuelling spill during dredging in Mermaid Sound (a small sized spill) P_1 Risk = 4.1 x 10^{-2} pa.

The primary risk of all other scenarios listed in **Table 7-37** is < 1 in 10 000 (corresponding to a probability of highly unlikely) and on this basis alone they are not considered to represent credible scenarios.

The locations of the potential spill release sites for the scenarios included in the technical hydrocarbon spill report represent the most conservative (that is, worst case) assessment, as they have been selected to maximise predicted contact with sensitive resources. The following description of the fate and behaviour of spilled hydrocarbons makes reference to a number of islands and other locations within the Dampier Archipelago. These locations are shown in **Figure 7-59**.

The scenarios presented assume that no mitigation measures are applied in the event of a pipeline failure and dry break coupling failure during load-out of condensate to a tanker berthed alongside the load-out jetty. Under this scenario, condensate would be discharged directly onto the surface waters and therefore spreading and evaporation will be the primary mechanisms of weathering.

Leakage of the Gas Trunkline in Mermaid Sound – Small Sized Spill (2.16 m³)

P_1 Risk = 1.7 x 10^{-5} pa

The rate of leakage of condensate from a 5 cm diameter hole in the gas trunkline would be low due to the low condensate-to-gas ratio in the pipeline, and condensate would be atomised by the release of gas through the perforation.

The results from the worst-case season (transitional) for a leak of condensate from an alternative trunkline route that was originally considered through Mermaid Strait (**Section 3**) indicated that condensate was predicted to form a thin sheen that would evaporate relatively quickly (<3 hrs). Slicks thicker than 0.001 mm are not expected beyond a few hundred metres horizontally from the release point. Entrained concentrations of condensate are also expected to be low (<1 ppm within 50 m from the release point).

Based on the results for the Mermaid Strait trunkline option, a similar size leak from the gas trunkline through Mermaid Sound is likely to result in similar localised fate and behaviour (that is, no predicted contact with the shoreline).

Failure of the Condensate Load-Out Pipeline During the Loading of an Export Tanker in Mermaid Sound – 'Dry Break Coupling Fails' – Medium Sized Spill (566 m³)

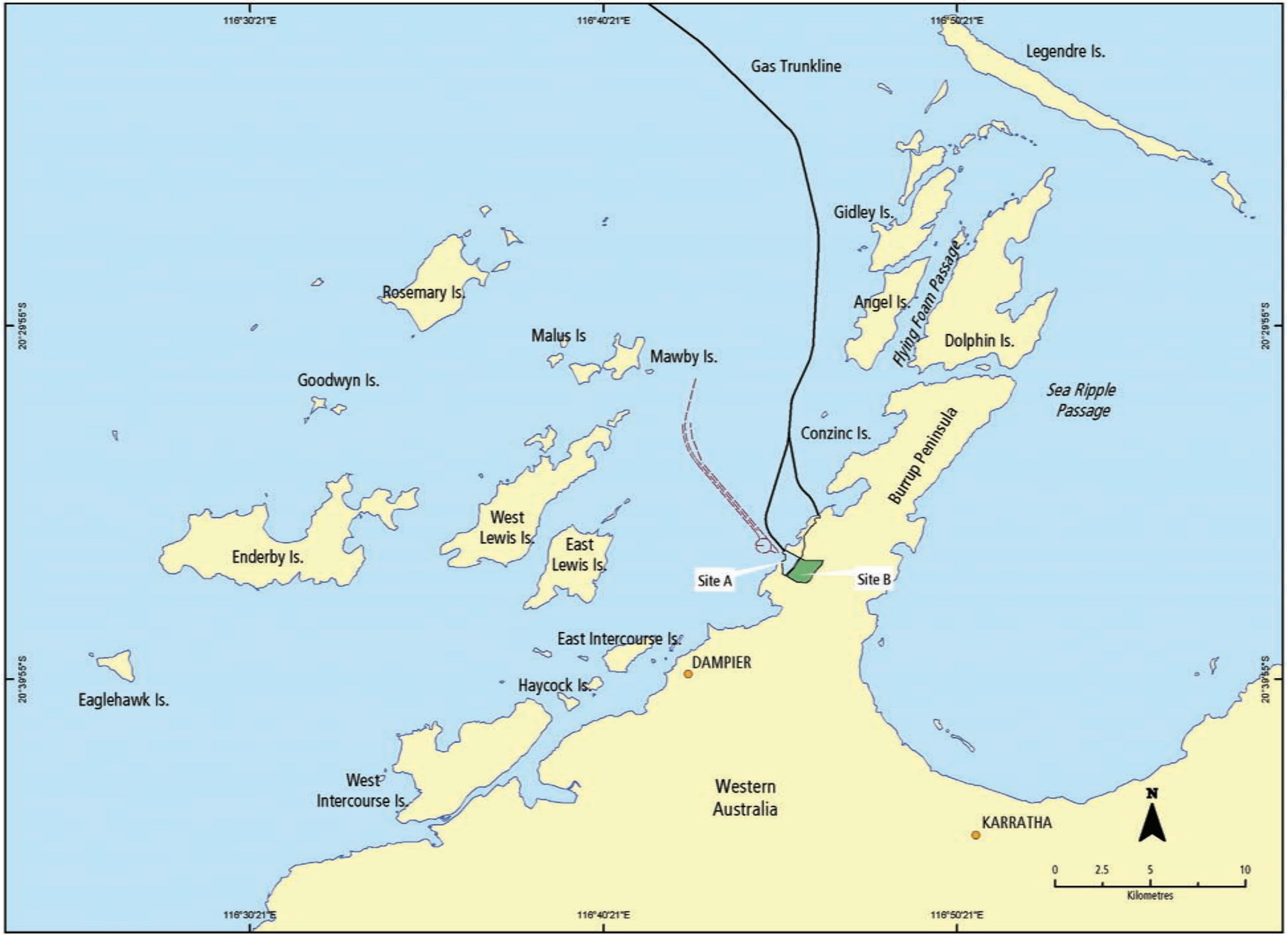
P_1 Risk = 4.9 x 10^{-5} pa

Stochastic modelling indicates that the central and eastern waters of the Dampier Archipelago would be predicted to experience surface slicks >0.001 mm, although there are likely to be seasonal trends (**Figure 7-60**, **Figure 7-63** and **Figure 7-66**).

Tidal forces within the Dampier Archipelago are likely to strongly influence the behaviour of condensate on the sea surface. Due to the proximity of the load-out jetty to the Burrup Peninsula shoreline, surface slicks are expected to have a relatively high probability (35%) of exposure to shorelines during summer and transitional months when there is a high frequency of winds from the westerly, south-westerly and southerly sectors, equating to a combined 'P_1' x 'P_2' probability of approximately one in 500 000. Minimum drift times are expected to be as short as 30 minutes for the shorelines of the Burrup Peninsula and Withnell Bay. During winter months the habitats at East Lewis and West Lewis Islands are expected to have the highest probability (14%) of exposure from slicks, equating to a combined 'P_1' x 'P_2' probability of approximately one in 140 000 per annum.

The highest concentrations of entrained hydrocarbons reaching the shoreline were predicted to occur during summer months (**Figure 7-65**). Levels >100 ppm for periods >12 hours were predicted on the adjacent coast of the Burrup Peninsula, within Withnell Bay and south of Legendre Island. During winter, locations along the Burrup Peninsula are not expected to experience concentrations >1 ppm, although some areas of West Intercourse Island were predicted to receive instantaneous peak concentrations of >10 ppm of entrained condensate.

Figure 7-59 Reference Locations Within Dampier Archipelago



Failure of the Condensate Load-Out Pipeline During the Loading of an Export Tanker in Mermaid Sound – 'Dry Break Coupling Activated' – Small Sized Spill (10 m³)

P_1 Risk = 1.6×10^{-2} pa

This scenario is similar to the previous scenario, although it assumes that safeguard measures will be implemented, including activation of dry break couplings, in the event of an accidental leak to arrest the spill. Accident analysis indicated that the volume of condensate that would be released as a result of this scenario would be significantly lower than during pressurised load-out. The estimated maximum release volume for this scenario is 10 m³ with a discharge period of <1 hour.

The stochastic modelling indicates a similar seasonal trend in terms of spill trajectory when compared to the results for a spill where the dry break coupling fails. Slicks >0.001 mm are predicted to drift over the eastern area of Mermaid Sound during summer and transitional months and the western area during winter months (**Figure 7-71** and **Figure 7-73**). The highest probability of shoreline exposure will be during the summer months (34%) equating to a combined $P_1 \times P_2$ probability of approximately 1 in 200 per annum.

Exposure risk estimates for surrounding coastline are predicted to be similar to those predicted for the pressurised load-out scenario (dry break coupling fails) as shown in **Figure 7-70**, **Figure 7-72** and **Figure 7-74**. Simulations indicated that there is predicted to be no concentrations of entrained condensate exceeding the 1 ppm threshold.

Operational Diesel Spill During Dredging in Mermaid Sound – Small Sized Spill (2.5 m³)

P_1 Risk = 4.1×10^{-2} pa

Stochastic modelling simulations indicate that a small spill of diesel (2.5 m³) from a refuelling accident would spread rapidly and that approximately 40% of the initial mass would be lost to evaporation over the first 24 hours. The maximum surface slick (thickness >0.001 mm) area is predicted to be 5 km². Shorelines to the north and south of the release point were the most likely beaching points for surface slicks (**Figure 7-75** to **Figure 7-80**). Potential risks to shoreline habitats from slicks are likely to be lowest during winter months as the most frequent trajectory was westwards away from the coastline. In addition, slicks are likely to evaporate quickly to disperse below the threshold of 0.001 mm before reaching the shoreline to the west of the release point. The highest probability of shoreline exposure will be during summer months (32%), equating to a combined $P_1 \times P_2$ probability of approximately one in 1000 per annum.

While diesel is predicted to entrain, concentrations are not predicted to exceed the minimum threshold (1 ppm) at any location during any single season.

Figure 7-60 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m³ of Condensate from Loading of a Condensate Tanker during Summer Months (assuming no intervention)

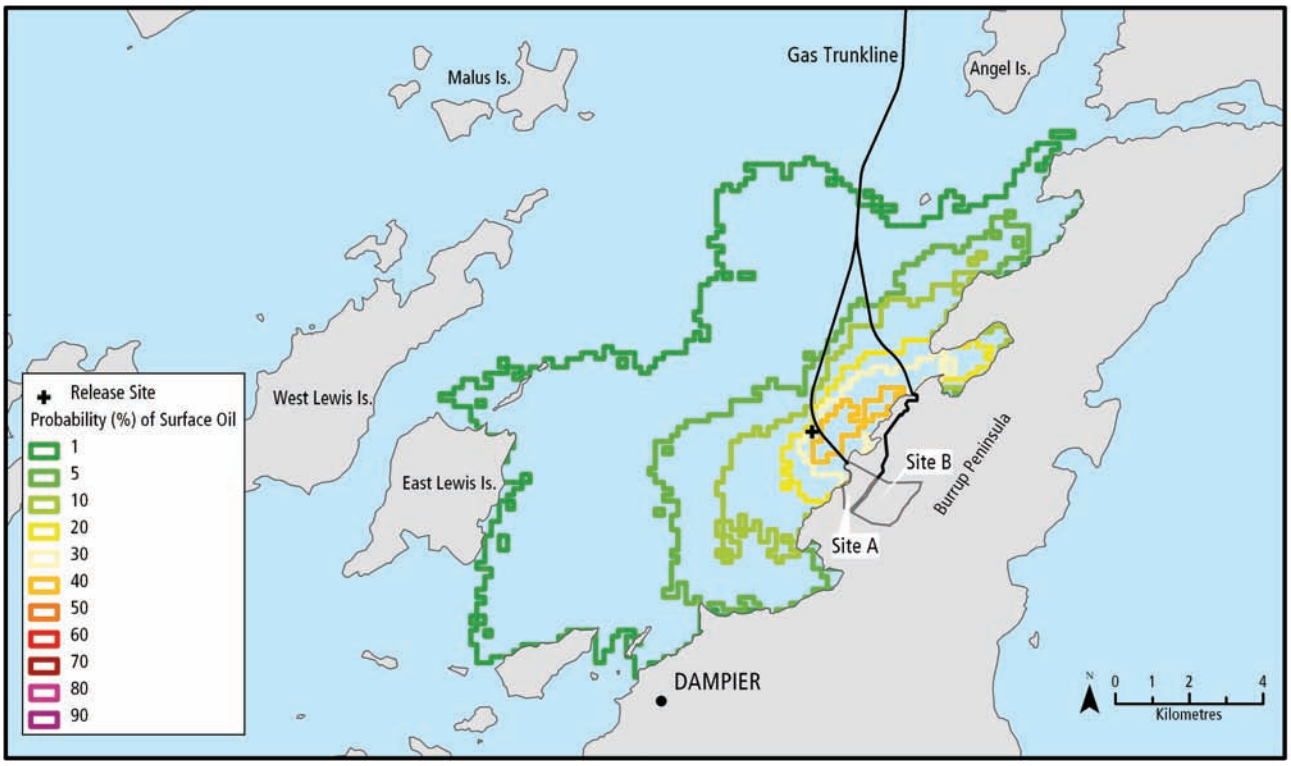


Figure 7-61 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m³ of Condensate from Loading of a Condensate Tanker during Summer Months (assuming no intervention)

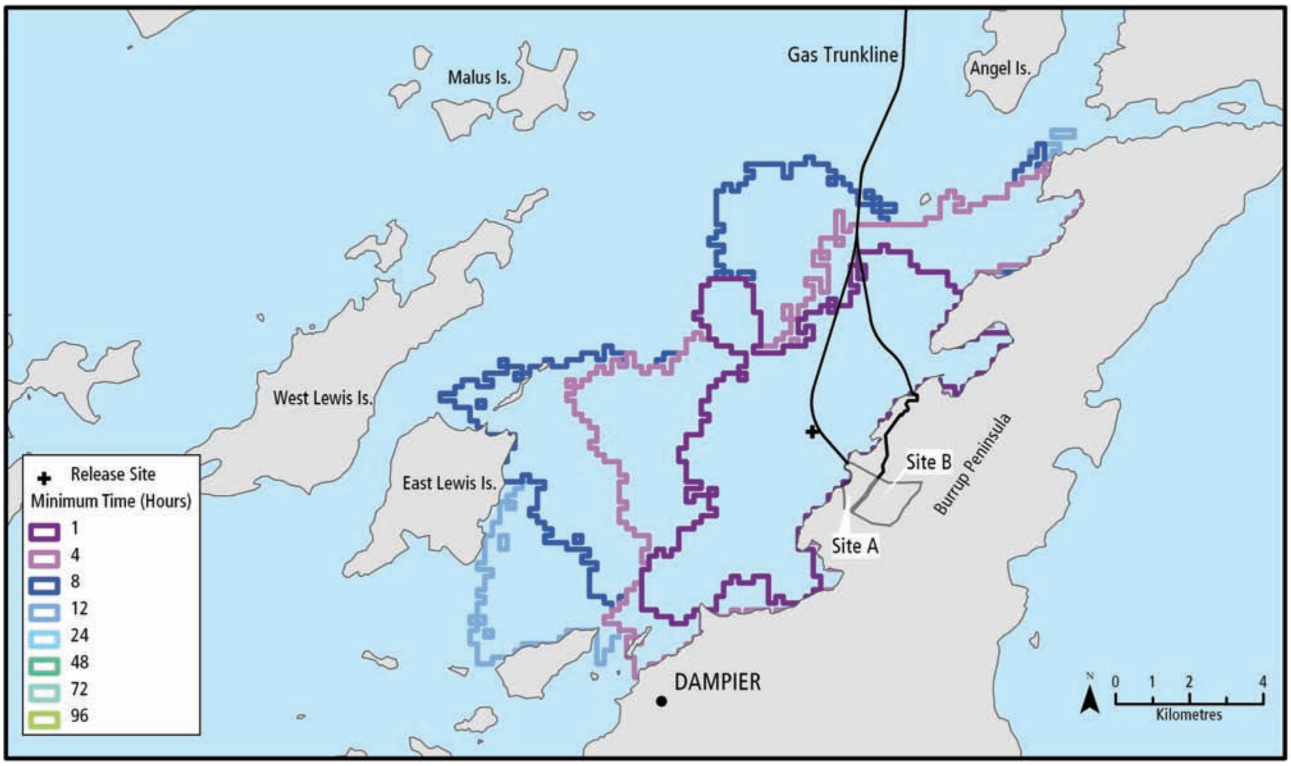


Figure 7-62 Highest Instantaneous Concentration of Entrained Hydrocarbons resulting from a Spill of 566 m^3 of Condensate from Loading of a Condensate Tanker during Summer Months (assuming no intervention)

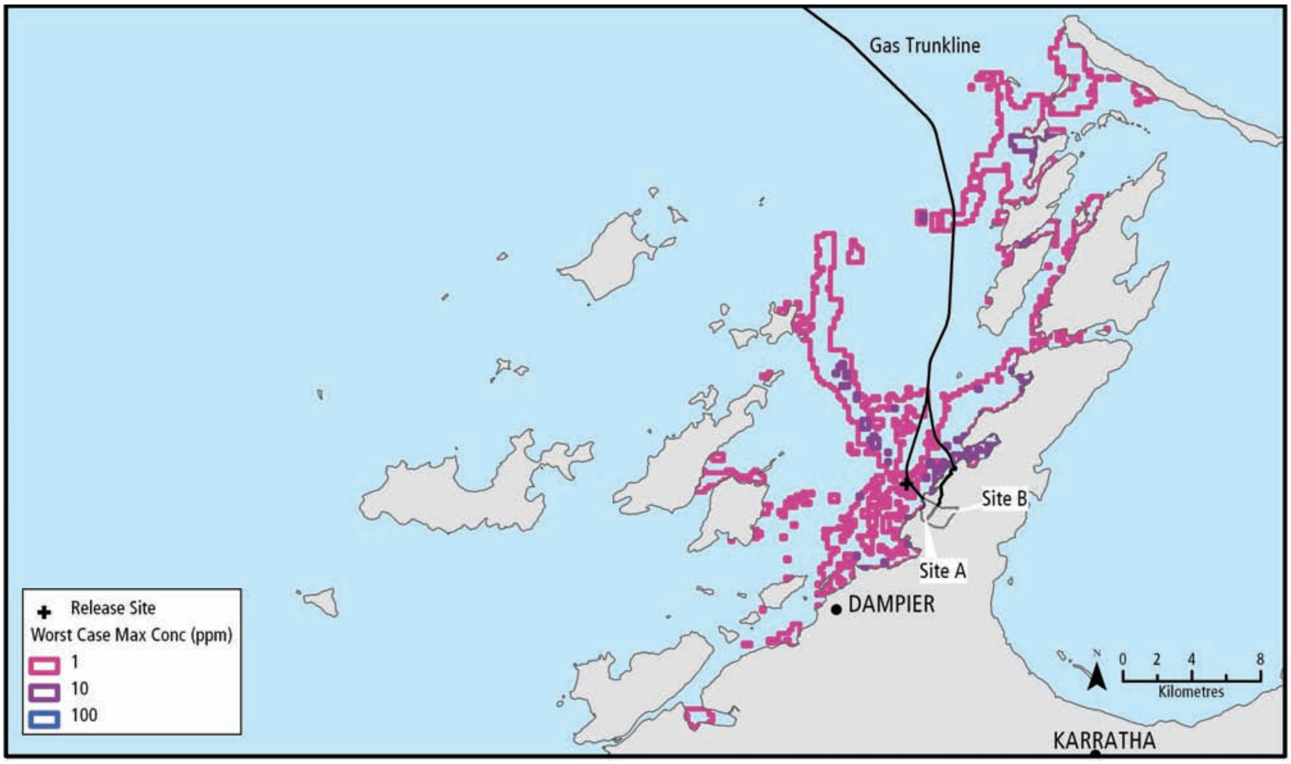


Figure 7-63 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m^3 of Condensate from Loading of a Condensate Tanker during Winter Months (assuming no intervention)

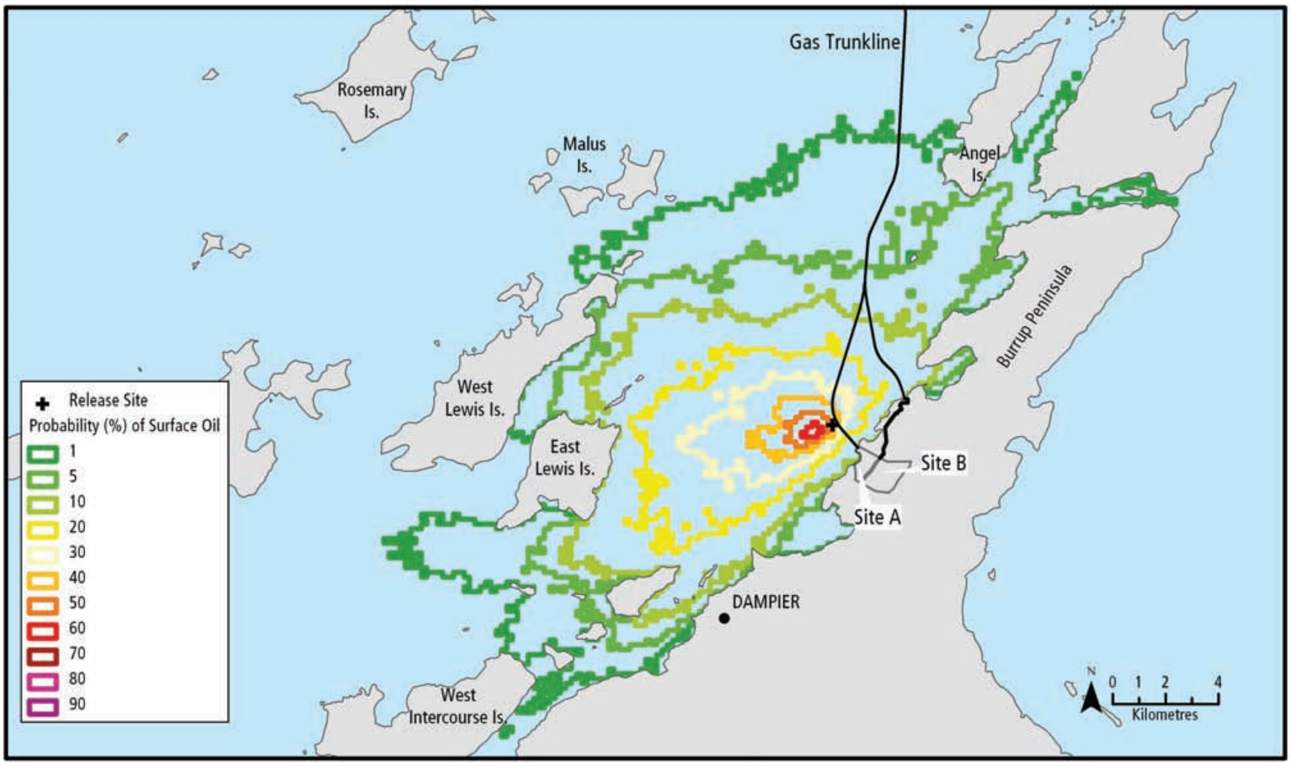


Figure 7-64 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m^3 of Condensate from Loading of a Condensate Tanker during Winter Months (assuming no intervention)

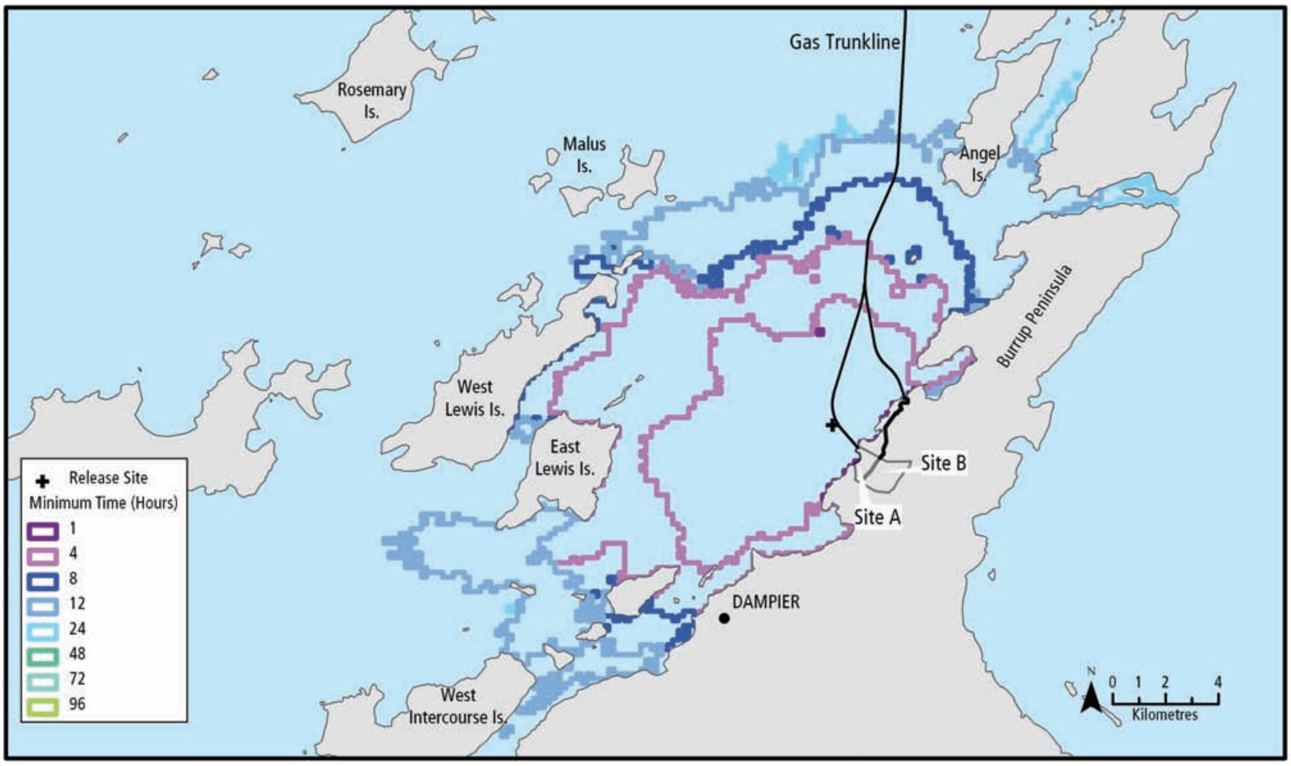


Figure 7-65 Highest Instantaneous Concentration of Entrained Hydrocarbons resulting from a Spill of 566 m^3 of Condensate from Loading of a Condensate Tanker during Winter Months (assuming no intervention)

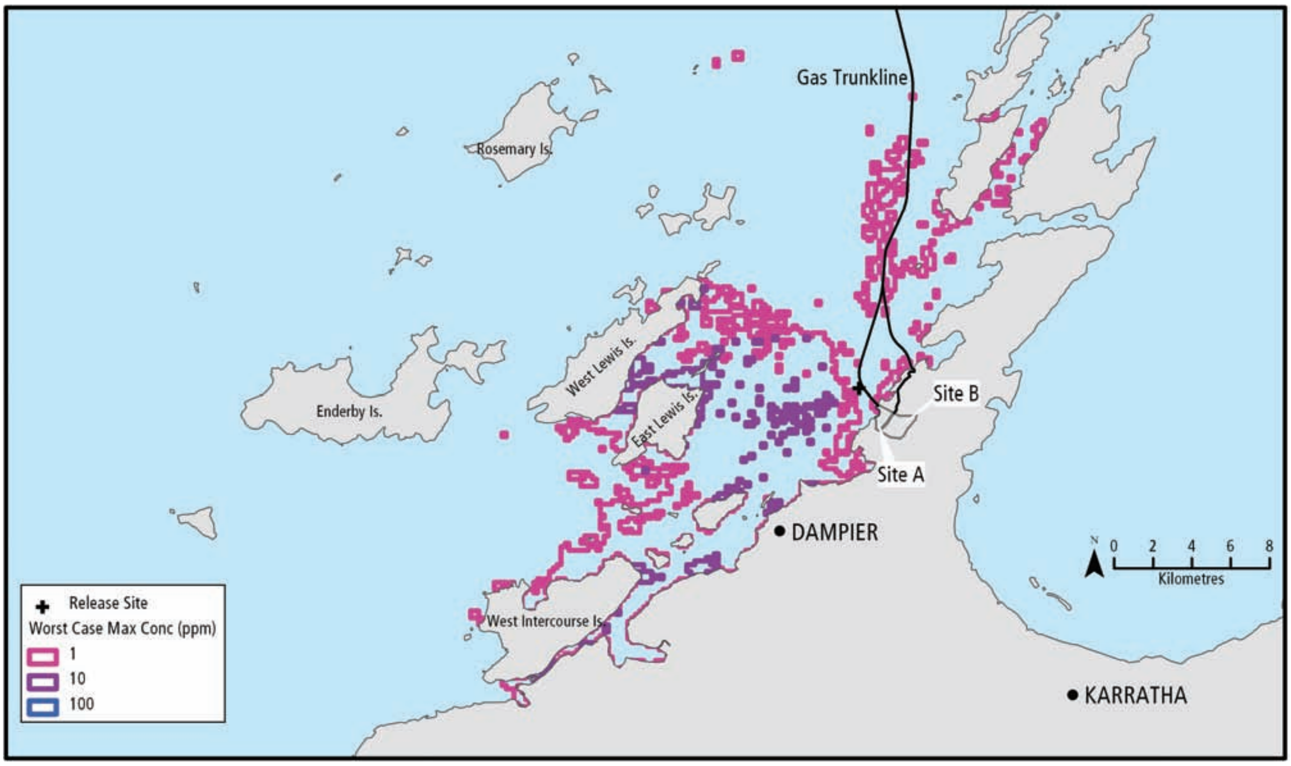


Figure 7-66 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m³ of Condensate from Loading of a Condensate Tanker during Transitional Months (assuming no intervention)

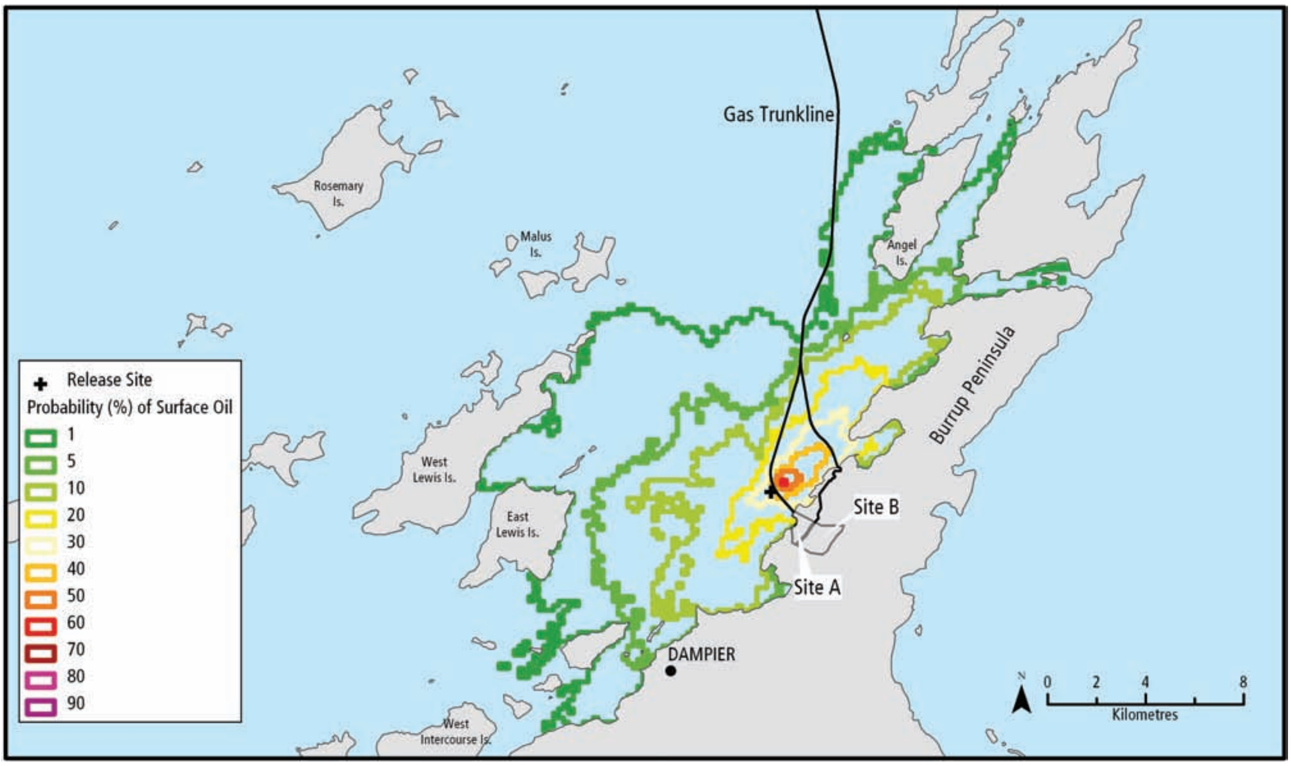


Figure 7-67 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 566 m³ of Condensate from Loading of a Condensate Tanker during Transitional Months (assuming no intervention)

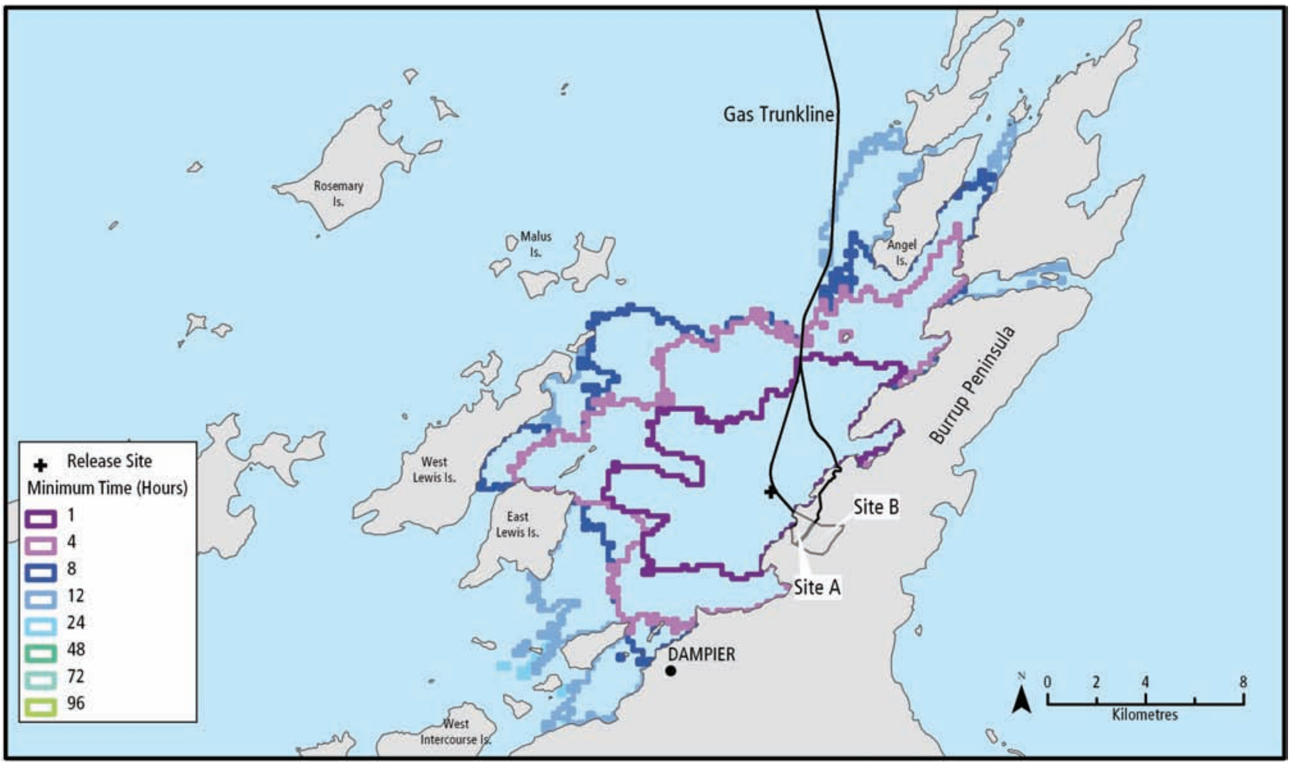


Figure 7-68 Highest Instantaneous Concentration of Entrained Hydrocarbons resulting from a Spill of 566 m^3 of Condensate from Loading of a Condensate Tanker during Transitional Months (assuming no intervention)

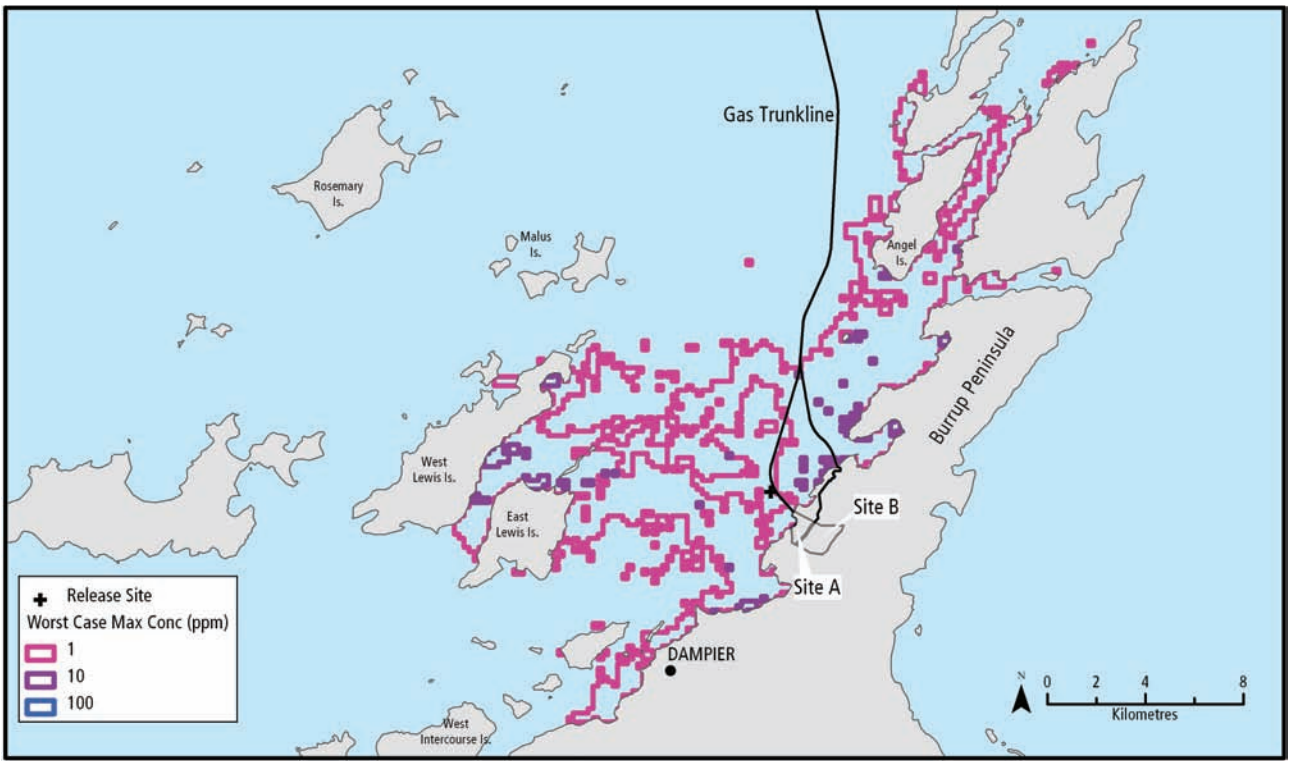


Figure 7-69 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m^3 of Condensate from Loading of a Condensate Tanker during Summer Months (assuming no intervention)

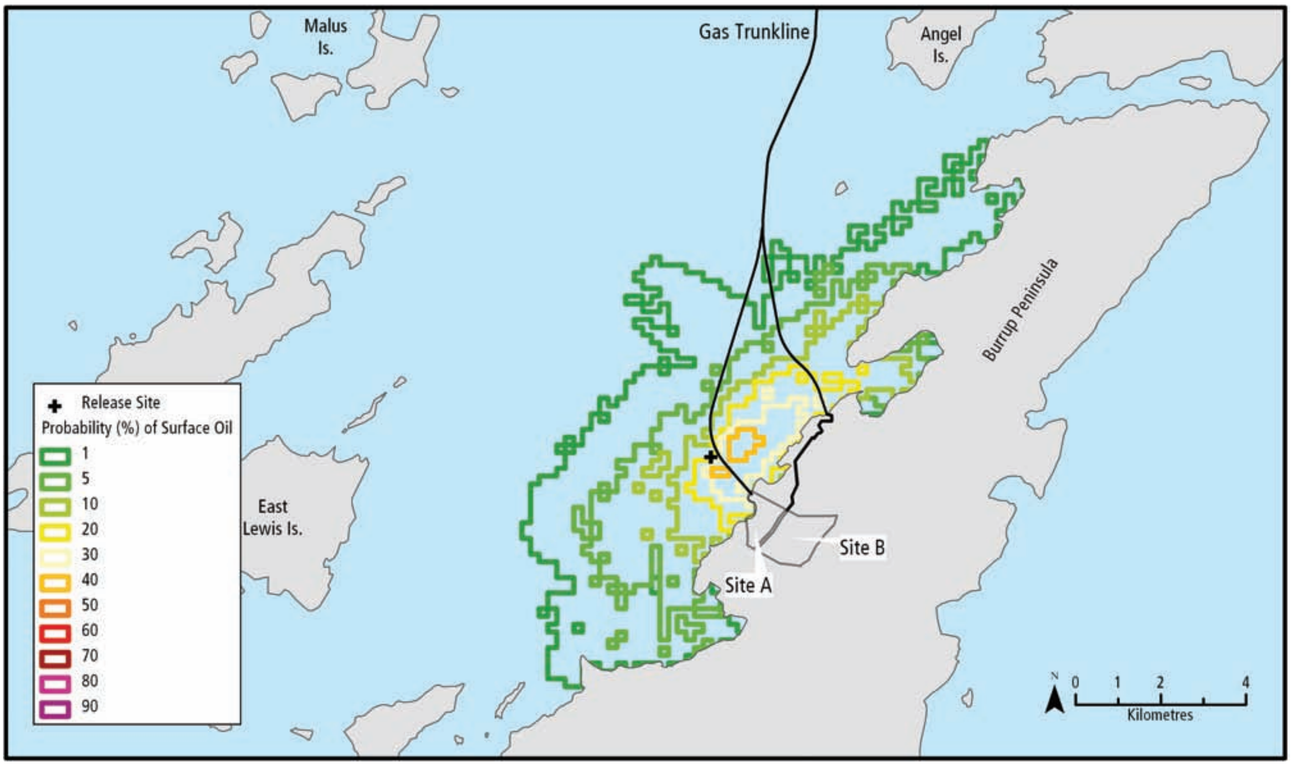


Figure 7-70 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m^3 of Condensate from Loading of a Condensate Tanker during Summer Months (assuming no intervention)

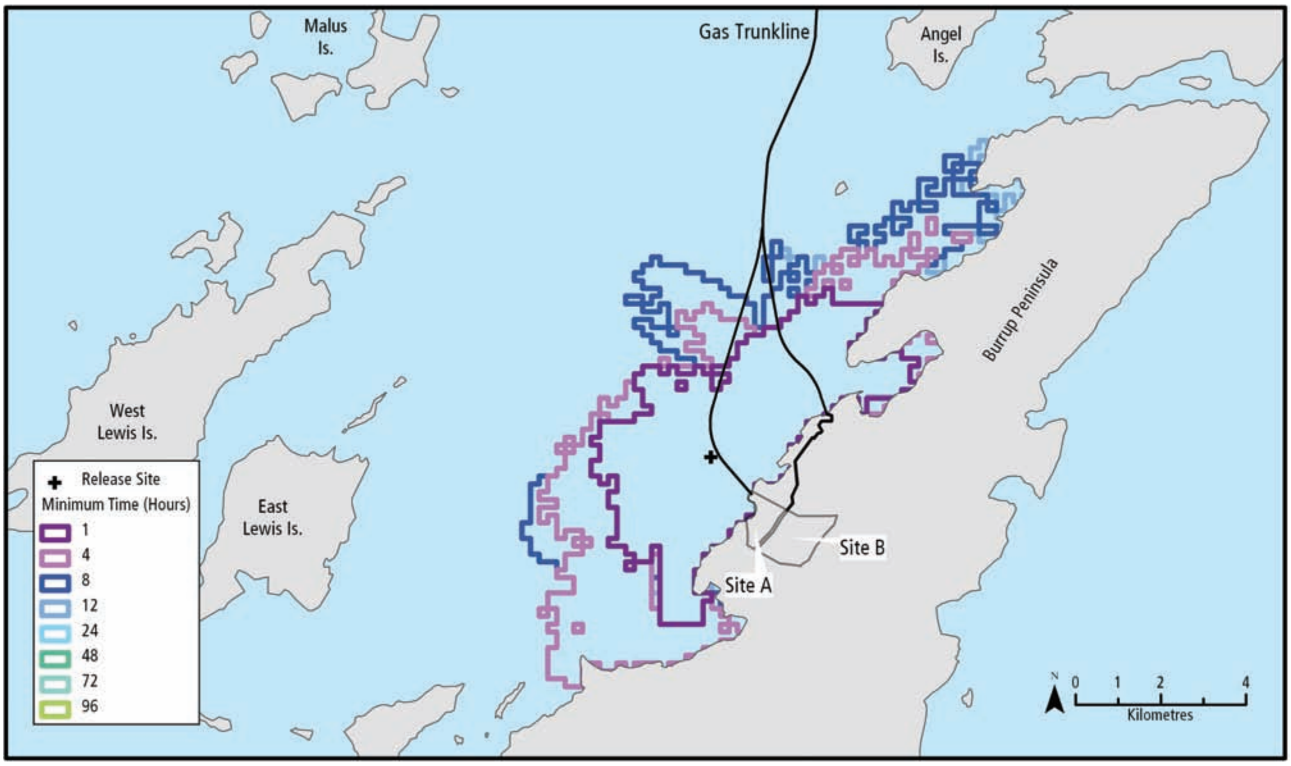


Figure 7-71 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m^3 of Condensate from Loading of a Condensate Tanker during Winter Months (assuming no intervention)

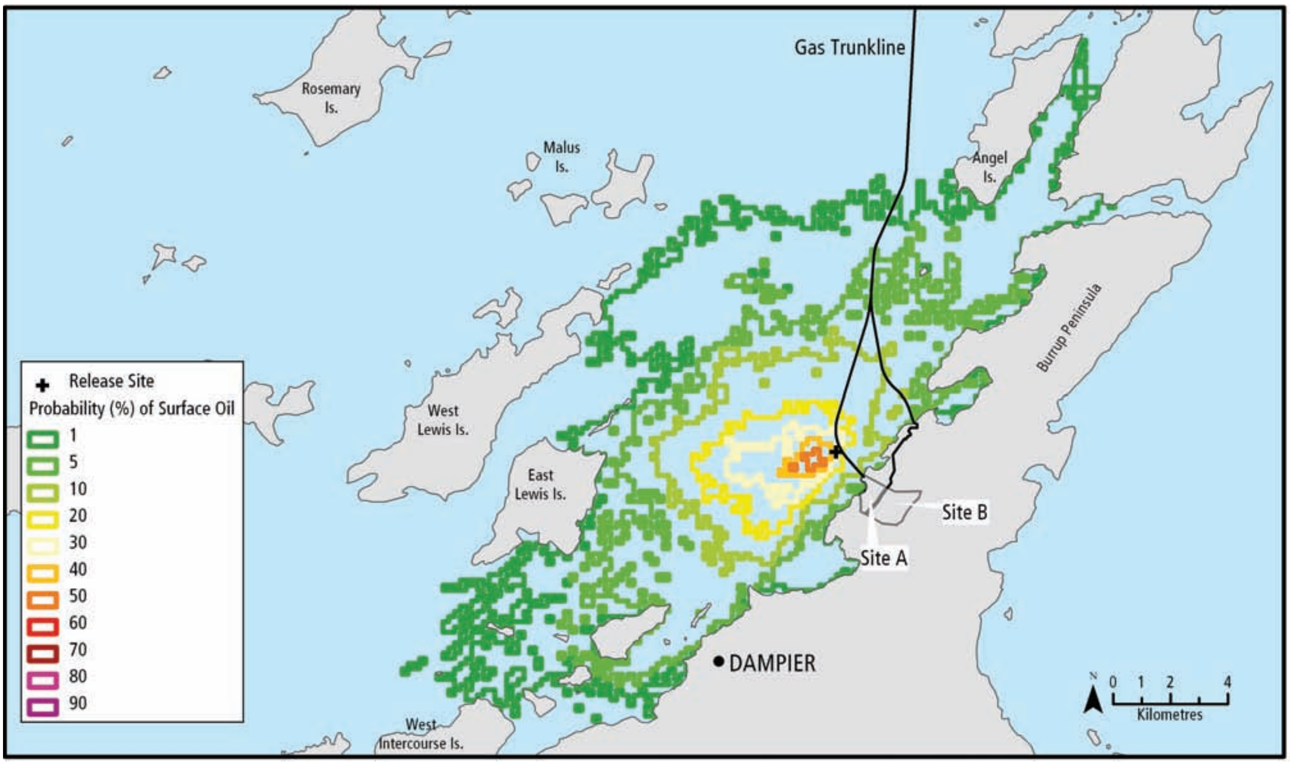


Figure 7-72 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m^3 of Condensate from Loading of a Condensate Tanker during Winter Months (assuming no intervention)

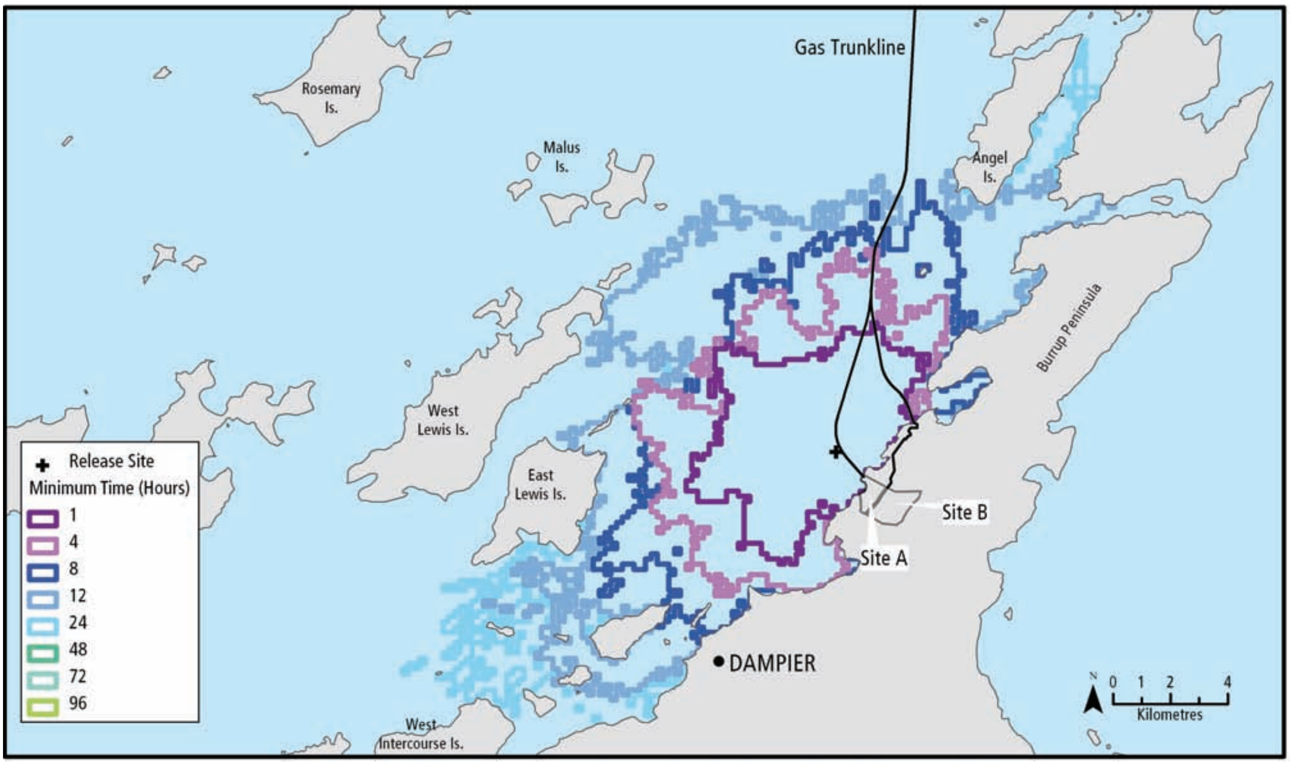


Figure 7-73 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m^3 of Condensate from Loading of a Condensate Tanker during Transitional Months (assuming no intervention)

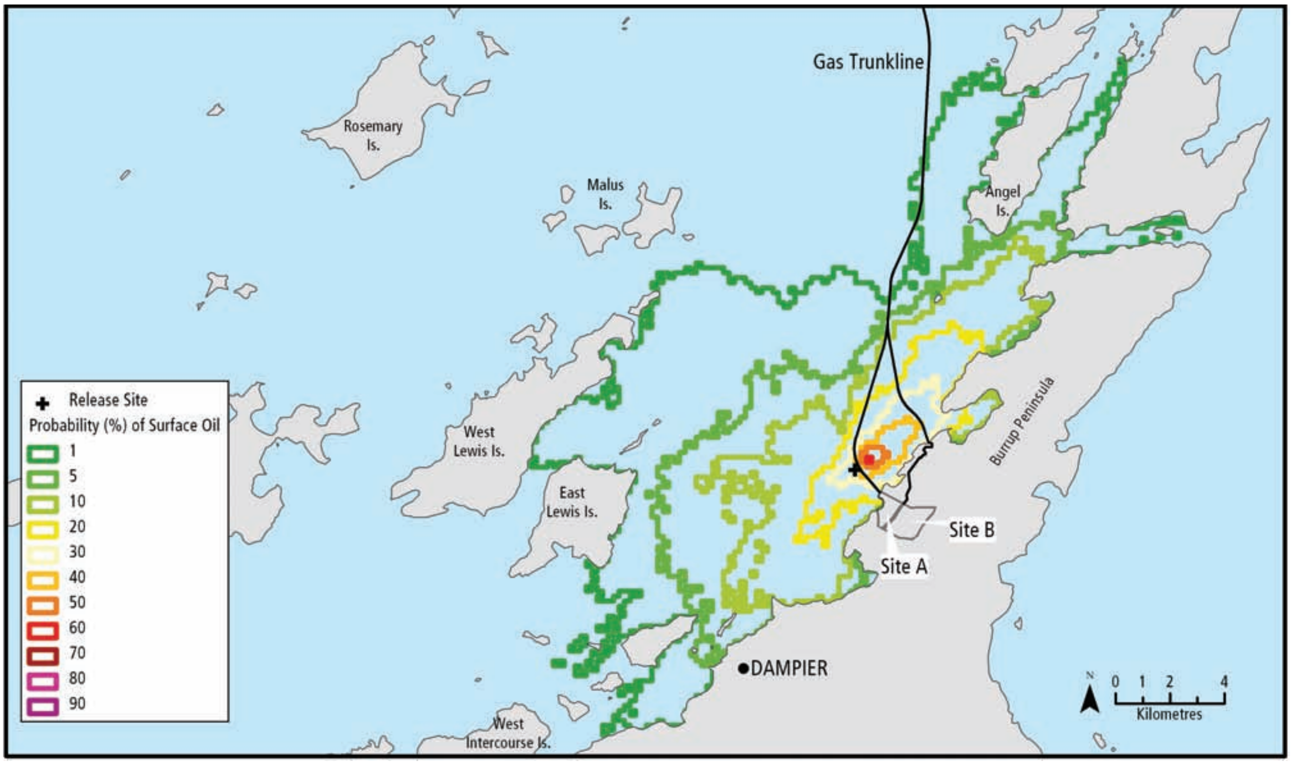


Figure 7-74 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Leak of 10 m³ of Condensate from Loading of a Condensate Tanker during Transitional Months (assuming no intervention)

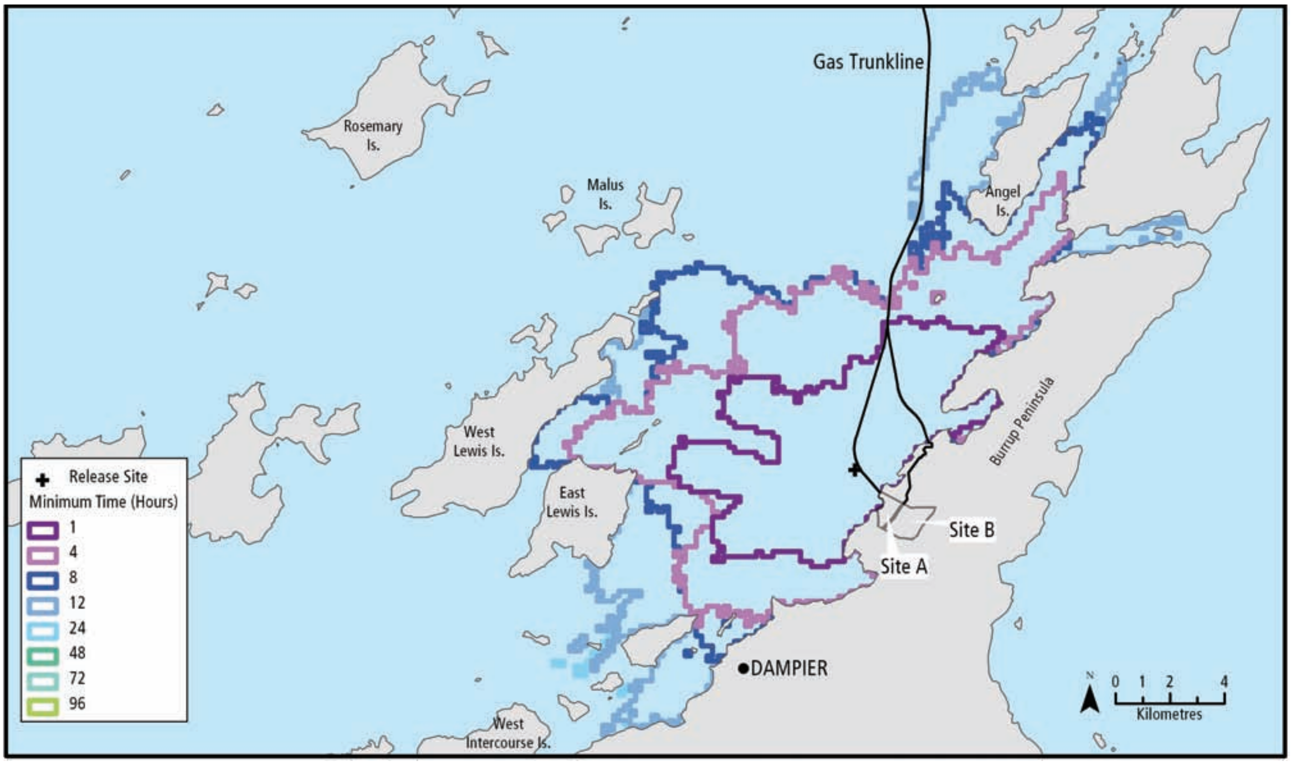


Figure 7-75 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m³ of Diesel from a Dredge Vessel Refuelling Accident during Summer Months (assuming no intervention)

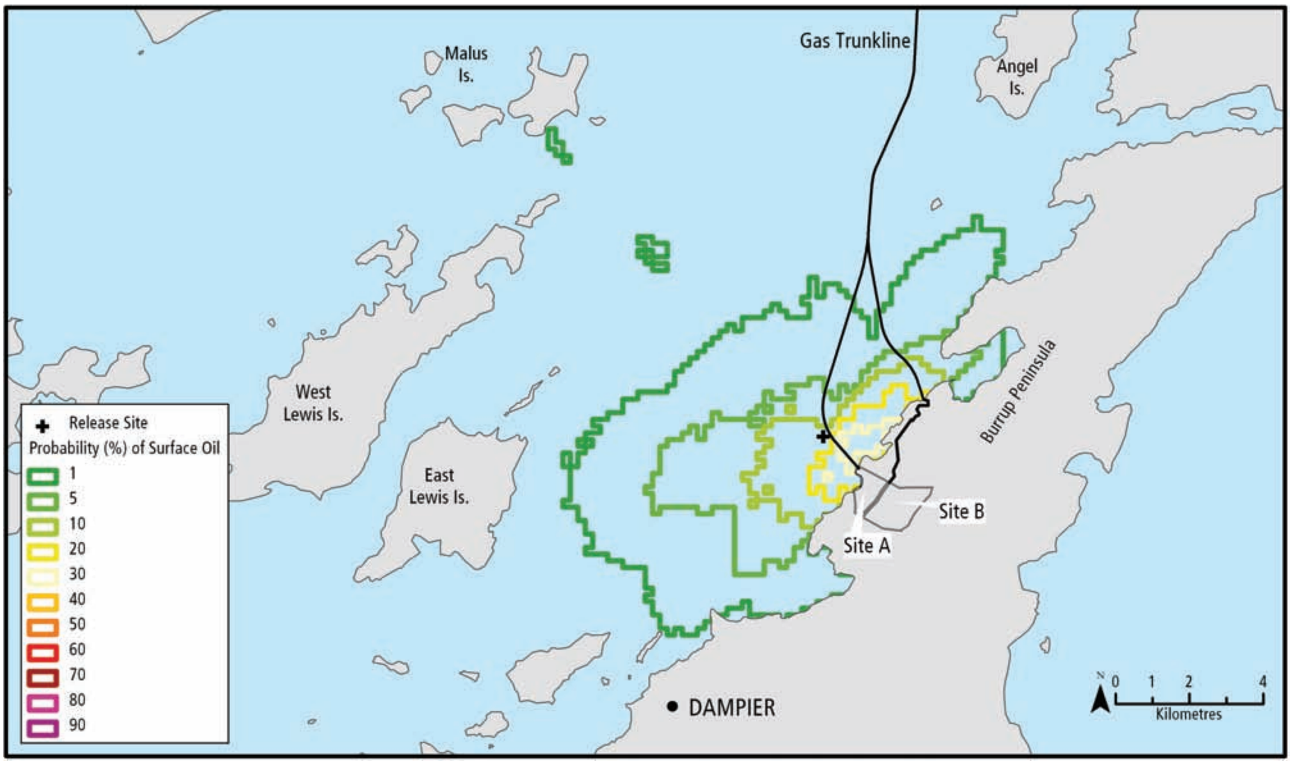


Figure 7-76 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m³ of Diesel from a Dredge Vessel Refuelling Accident during Summer Months (assuming no intervention)

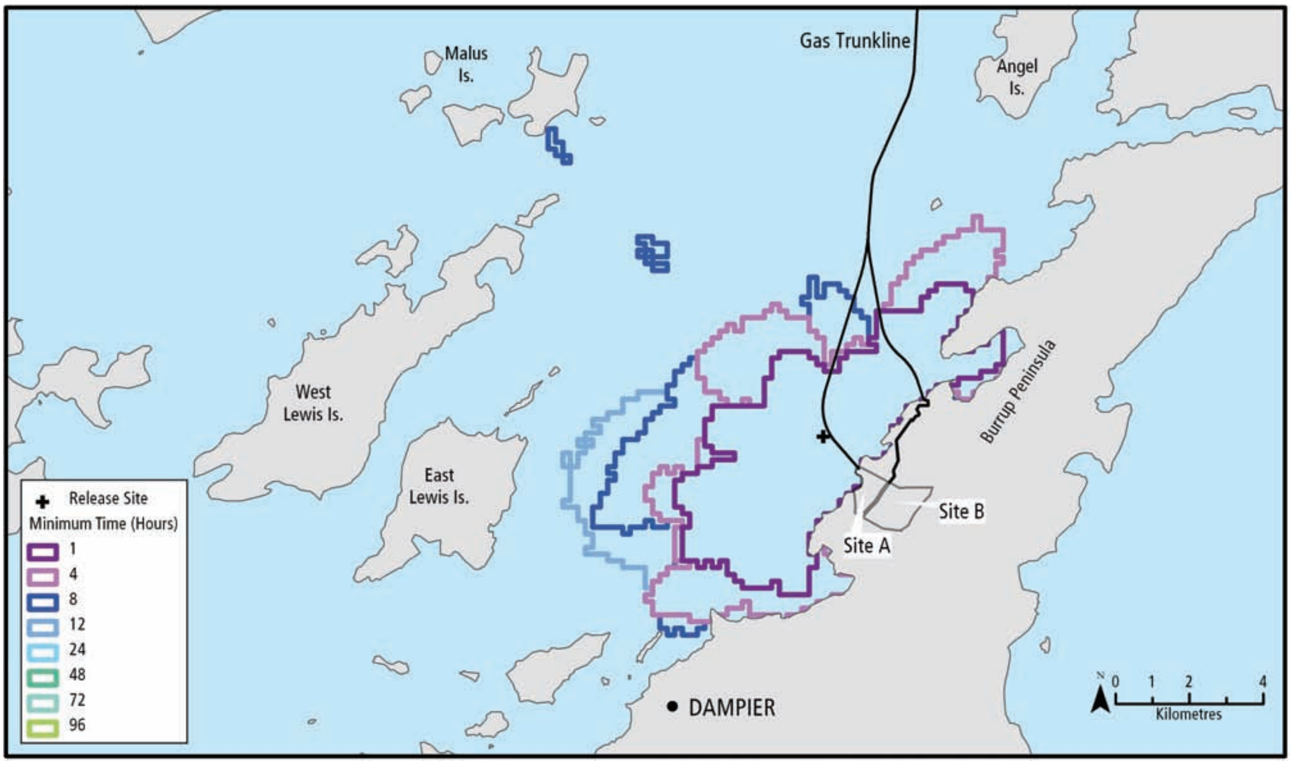


Figure 7-77 of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m³ of Diesel from a Dredge Vessel Refuelling Accident during Winter Months (assuming no intervention)

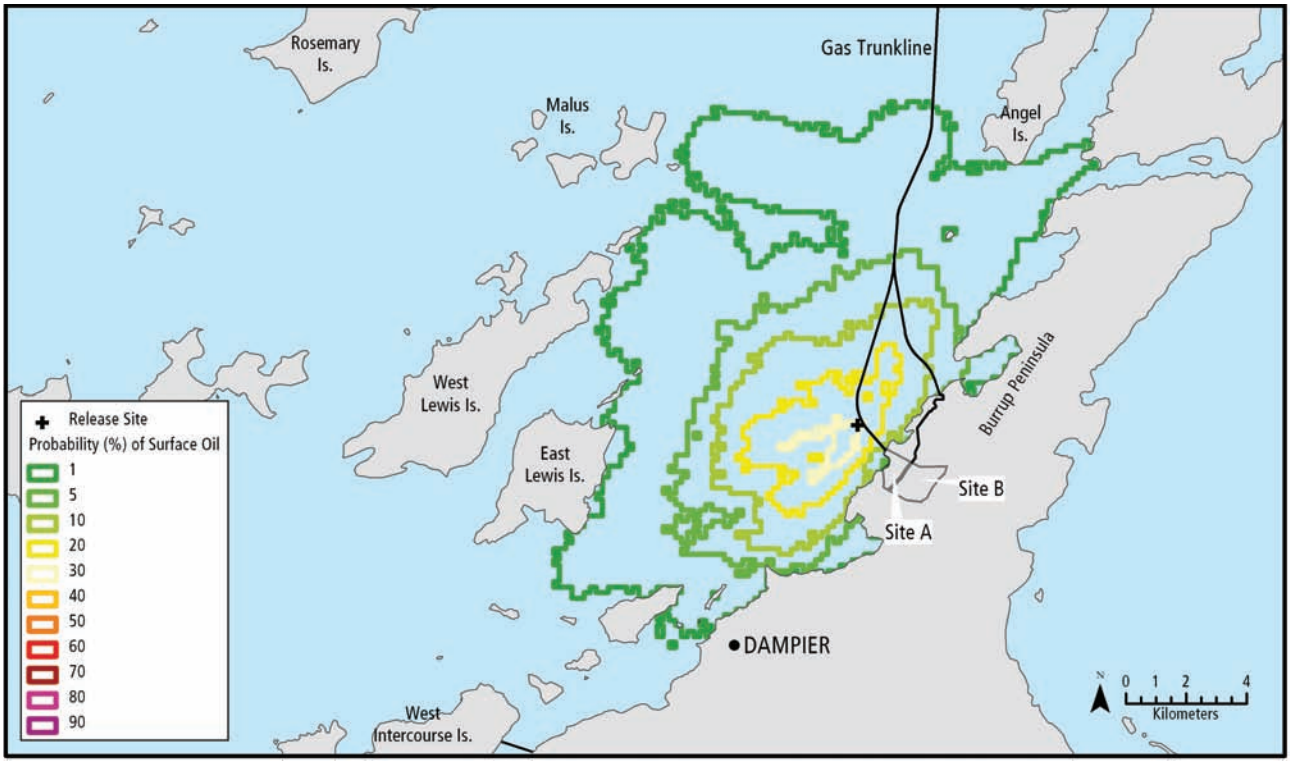


Figure 7-78 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m^3 of Diesel from a Dredge Vessel Refuelling Accident during Winter Months (assuming no intervention)

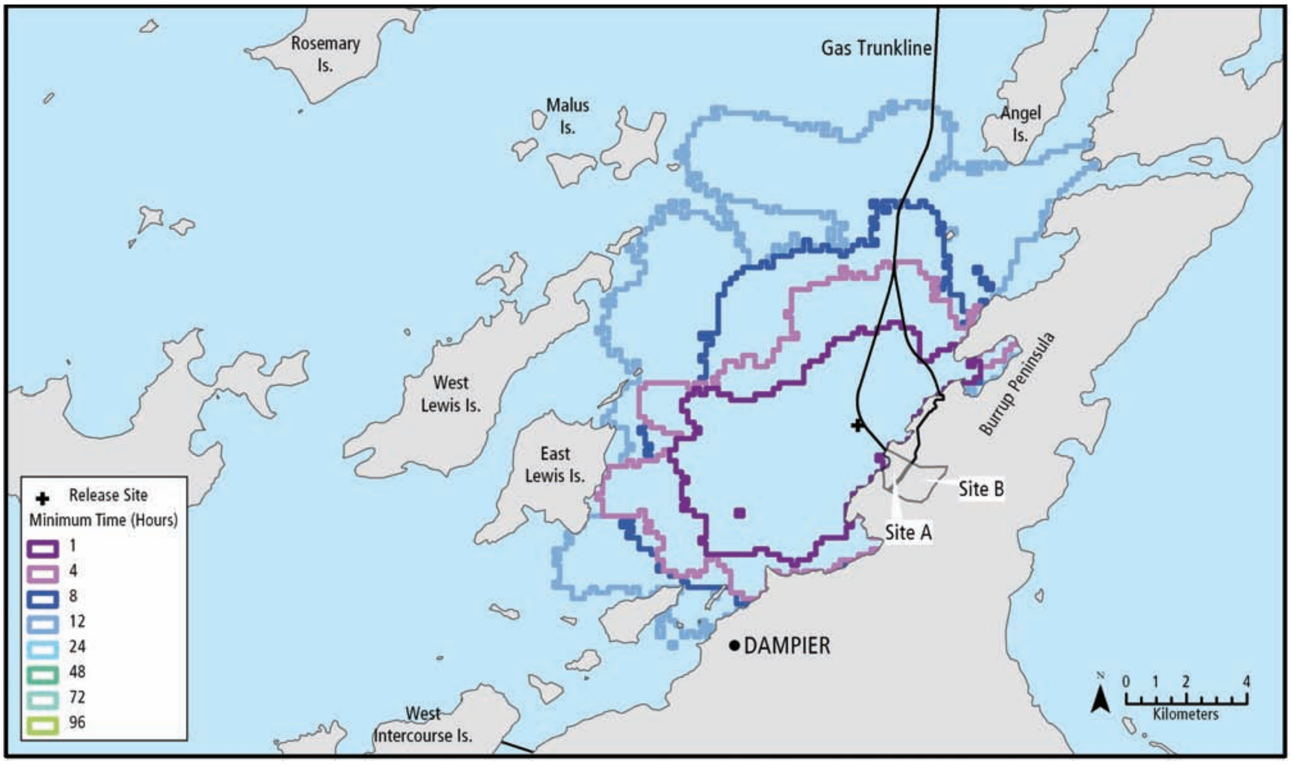


Figure 7-79 Probability of Surface Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m^3 of Diesel from a Dredge Vessel Refuelling Accident during Transitional Months (assuming no intervention)

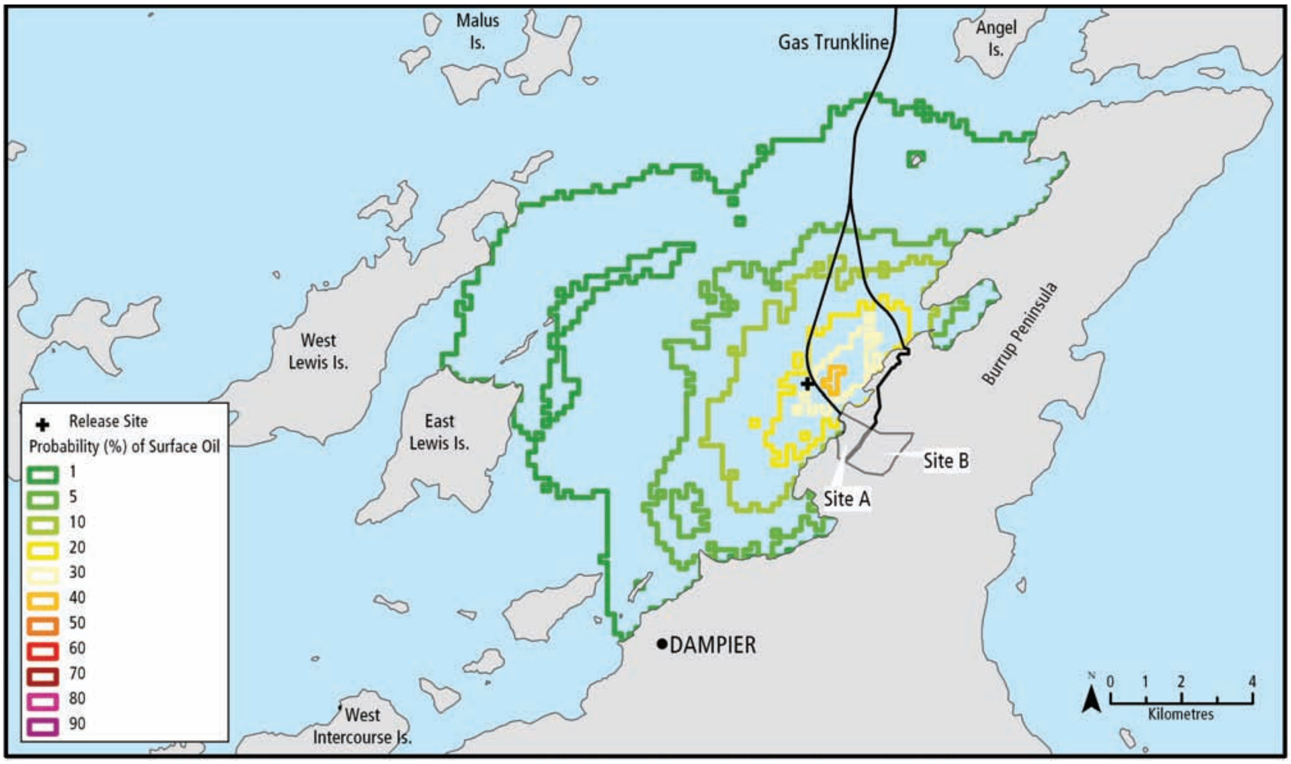
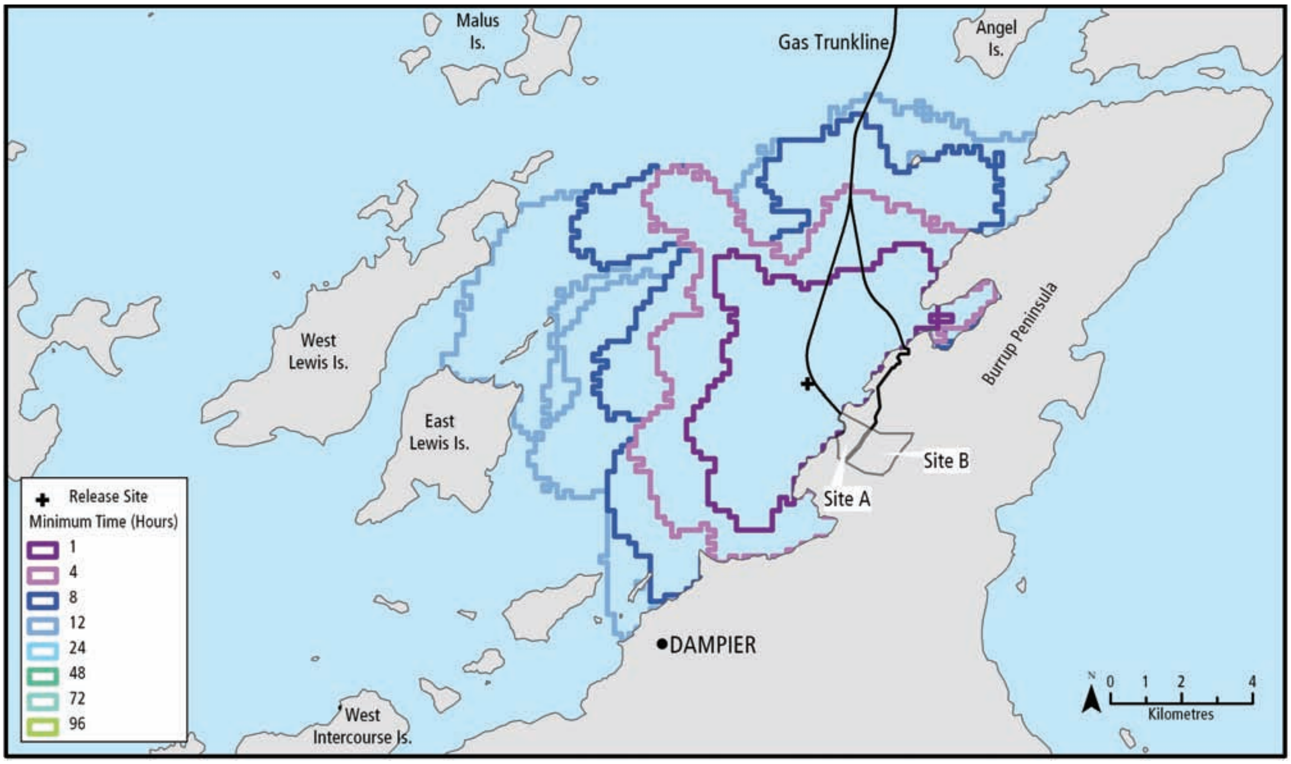


Figure 7-80 Minimum Time before Hydrocarbon Exposure (>0.001 mm) resulting from a Spill of 2.5 m^3 of Diesel from a Dredge Vessel Refuelling Accident during Transitional Months (assuming no intervention)



7.10.6 Effects on Biota

7.10.6.1 Potential Impacts

Numerous scientific studies and laboratory tests have previously been undertaken to assess the cause and effect relationship between spilled hydrocarbons and environmental receptors. Mortalities of marine fauna from large scale hydrocarbon spill events are relatively rare and when mortality does occur, it is typically associated with spills that are localised, short lived and in areas with poor water exchange. No large scale hydrocarbon spills (that is, greater than 100 m^3) have occurred in Australian waters during oil and gas exploration and production.

The main environmental effects commonly associated with hydrocarbon spills are:

- Physical effects: including coating and/or smothering leading in certain cases to contamination and mortality. Severe coating can restrict vital life functions including the ability to feed, and to maintain insulation, respiration and movement/migration.
- Chemical and biological effects (toxicity and bioavailability): including sub-lethal and lethal effects caused mainly by the water soluble aromatic hydrocarbons (for example, benzenes) and the lower molecular weight polycyclic aromatic hydrocarbons (PAHs) which exhibit significant acute toxicity and other adverse effects to marine organisms (Scannell et al. 2005). Sub-lethal effects limiting organisms' capacity to feed, grow and reproduce, and chronic exposure to hydrocarbons at varying concentrations can lead to mortality. The most toxic components of hydrocarbons are those that evaporate more rapidly on the sea surface and as such large scale mortality events are rare, short lived and associated with spills of light refined products or fresh crude. Condensate also evaporates significantly quicker that crude oil. Marine diesel is toxic to a variety of marine species and retains its toxic properties during weathering due to the slow loss of the more toxic light fractions.

The following section describes the environmental sensitivities that may be impacted by any of the hydrocarbon spill scenarios described in this part of the Draft PER. It also identifies the environmental risk to each of these receptors associated with varying size spills to each of these receptors.

The consequences of a particular spill event are determined subjectively taking into consideration a range of issues including:

- How large is the spill (small, medium or large)?
- What is the spill duration (minutes, hours, days)?
- What are the prevailing climatic and oceanographic conditions and seasonal variations?
- What is the release depth and period of surface exposure/ water column entrainment?

- How susceptible are individual species and habitats to condensate and diesel spills?
- What is the local, regional, national and international significance of the affected species and/or habitat?
- What are the recovery timeframes for species and/or habitats affected by hydrocarbon spills?

Plankton

A number of field laboratory studies have been undertaken to document the effects of hydrocarbon exposure on plankton. As expected, the earlier development phases of the life-cycle (egg, larval and juvenile stages) will be more susceptible than adults. Potential impacts to plankton from a large spill event are likely to be limited given that plankton populations are large and widely distributed. Phytoplankton will be most sensitive when a mass spawning event occurs, however the likelihood of a large hydrocarbon spill coinciding with a mass spawning event is considered remote and potential impacts are considered slight.

Potential impacts are likely to be more significant should the oil spill slick coincide with, and be transported to, a mass synchronous spawning event, such as that which is known to occur for corals. Recently spawned gametes and larvae would be especially vulnerable to oil spill effects since they are generally positively buoyant and would therefore be exposed to surface slicks. However, given the remote likelihood of this event, the predicted environmental risk to plankton from hydrocarbon spills is low even for large oil spills (1000 m^3 or less).

Algae

Potential environmental effects to algae depend on the degree of direct exposure and how much of the hydrocarbon adheres. The presence of fine hairs and other morphological features will influence the amount of hydrocarbon that will adhere, and a review of field studies conducted after spill events by Connell and Miller (1981) indicated a high degree of variability in the level of impact. In all instances the algae appeared to be able to recover rapidly from even very heavy oiling.

Algae communities are widespread within the Dampier Archipelago and are commonly associated with submerged limestone pavement habitat (**Section 6.3.1**). A small, medium and large sized hydrocarbon spill (either of condensate or marine diesel) within the Archipelago is unlikely to significantly affect submerged algae communities, and potential impacts are considered slight or negligible.

Seagrass

The susceptibility of seagrasses to hydrocarbon spills depends largely on their distribution. Within the Dampier Archipelago, sea grasses are relatively sparse and are mainly found between Keast Island and Legendre Island and between West Intercourse Island and Cape Preston (CALM 2005). They are typically found in water depths to 10 m. In the event of a large hydrocarbon spill within the Dampier Archipelago the potential for direct contact with seagrass is extremely low, the exception being areas where seagrass colonise intertidal zones. In such zones, direct contact with the condensate will occur if the spill event reaches the area. Predictions of condensate concentrations in the water column resulting from credible spill events indicates that concentrations exceeding 1 ppm would not reach any subtidal seagrass meadows, and consequently the potential effect on seagrasses is considered to be slight or negligible.

Mangroves

Mangroves are important components of tropical ecosystems and provide nursery areas for a wide range of marine species and a source of organic matter and nutrients. Numerous studies have been undertaken to assess potential environmental effects of oil spills on mangroves (Duke et al. 1999). Typically, hydrocarbon slicks enter mangrove forests during high tides, and are deposited on the aerial roots and sediment surface as the tide recedes. Direct mortality of mangroves can occur from heavy oiling that covers breathing pores (lenticels) and from toxic substances contained within the oil which may impair the salt exclusion process (IPIECA 1993). Mangrove death is predicted whenever more than 50% of the leaves are lost (Evans 1985). Mangrove communities are found throughout the Dampier Archipelago region (**Section 6.3.1**), and important mangrove stands are found at Withnell Bay, Conzinc Bay, King Bay, Karratha Bay and Searipple Passage.

The recovery of mangroves after being affected by a hydrocarbon spill is considered to be slow, however, studies by Woodside at a condensate affected area within Mermaid Sound indicate that some individual *Avicennia marina* trees, previously recorded as dead, have shown evidence of recovery up to seven years after the initial condensate contact. During this period, mangrove seedlings have successfully colonised the disturbed area, along with more recent plantings and are successfully establishing, despite the residual hydrocarbon contamination.

Model predictions indicate that the P_2 probability of mangrove areas coming into contact with a slick of >0.0001 mm thickness is approximately 9% for a failure of the load-out pipeline during vessel loading (dry break coupling fails), 10% for a leak of the load-out pipeline during vessel loading (dry break coupling activated) and approximately 3% for an operational diesel spill during dredging. These P_2 probabilities assume no mitigation measures are implemented and equate to combined $P_1 \times P_2$ probabilities of 0.000004 per annum (failure of load-out pipeline during vessel loading – dry break coupling fails), 0.002 (leak of load-out pipeline during vessel loading – dry break coupling activated) and 0.001 per annum (diesel spill).

A small diesel spill during refuelling as part of pipeline dredging or construction of the navigation channel or a small condensate leak during vessel load-out is likely to result in moderate impacts to existing mangrove communities.

A medium sized spill resulting from load-out operations is likely to result in moderate impacts, given the lack of mangroves in the immediate vicinity of the jetty location.

Rocky Shore Habitats

Rocky shores vary in their sensitivity to oil spills. The survivorship of marine flora and fauna on wave exposed shorelines is likely to be higher than on sheltered rocky shorelines. Filter feeding species such as molluscs are potentially at risk of ingesting oil with lethal and various sub-lethal effects. Sub-lethal effects can include alteration in respiration rates, decrease in filter feeding activity, reduced growth rates, biochemical effects, increased predation, reproductive failure and mechanical destruction by waves as a result of an inability to maintain attachment to the substrate (Ballou et al. 1989; Connell and Miller 1981). Potential impacts resulting from a large or medium sized hydrocarbon spill are considered moderate, given the large areas of shoreline that are likely to be effected from these types of spills. Small spill events including pipeline leaks or refuelling accidents are likely to have slight or negligible impacts.

Coral Reef (including shoreline and fringing reef)

Potential impacts to coral reefs from hydrocarbon spills are most likely to be experienced by shoreline reef exposed to the sea surface, or subtidal reef exposed to exceptionally low tides and hydrocarbons that are entrained with the water column. These circumstances can cause direct smothering effects to corals. As corals secrete mucus, especially when stressed, the hydrocarbon droplets can adhere to them and in certain areas where high turbidity levels are experienced, hydrocarbons can adhere to mineral particles and sink, potentially affecting corals (IPIECA 1992). These effects are unlikely for condensate or diesel.

Adult coral colonies can be killed or injured by direct contact with oil, with reported symptoms ranging from no observable damage to complete breakdown of tissue (Johannes et al. 1972; Birkeland et al. 1976; Jackson et al. 1989 in Negris and Heyward 2000).

Numerous studies have documented damage to reefs and subsequent recovery following exposure to oil. However, relatively little research has been undertaken into the effects of hydrocarbons on coral reproduction and recruitment. As for other species, the early phases of the coral life-cycle are likely to be more sensitive to hydrocarbons than established colonies. Fadlallah (1983) noted that gametogenesis, brooding and broadcast spawning, fertilisation and larval metamorphosis may be disrupted by exposure to petroleum products (Negris and Heyward 2000). Coral spawning events are also likely to be sensitive to surface slicks, as is the subsequent 1–3 week period during which most larval metamorphosis and recruitment occurs. When eggs or larvae are released by corals into the surface waters, they float on or near to the water surface, increasing the risk of contact with hydrocarbons. Laboratory experiments indicate that the minimum concentration of dispersed oil that inhibits fertilisation of the scleractinian coral, *Acropora millepora*, after a 4-hr exposure period, is 0.0325 mg/l total hydrocarbon content (Negris and Heyward 2000), and that larval metamorphosis is inhibited for the same species at 0.0824 mg/l over a 24-hr exposure period. In the unlikely event of a hydrocarbon spill event in an area of coral reef and coinciding with a spawning event or in the 1–3 week period thereafter, the percentage of successful coral gamete fertilisation is likely to be diminished and the rate of settlement inhibited at concentrations <1 ppm.

In the event of a small or medium sized hydrocarbon spill within Mermaid Sound, either from vessel refuelling accidents or through failure of the load-out pipeline from the jetty potential impacts to coral communities will be limited, because the corals are located below the sea surface. There are few coral communities within close proximity to the location of the proposed Pluto LNG Development nearshore marine infrastructure. Potential impacts to corals from hydrocarbon spills are considered minor given that corals are located below the sea surface and are likely to be relatively robust.

Fish

Fish may be exposed to spilled hydrocarbons in different ways. They may be in direct contact with the oil spill which will contaminate their gills, and the water column may contain toxic and volatile hydrocarbon components that may be absorbed by their eggs, larvae and juvenile stages. They may also eat contaminated food. Low concentrations of hydrocarbons can affect reproduction and feeding in fish and shellfish. For example, mortality of adult *Clupea pallasi* (Pacific herring) has been induced by concentrations of 1 ppm crude oil total aromatics (96-h-LC50) (Hose et al. 1996), however despite a theoretical susceptibility to dissolved hydrocarbons, there is no evidence to suggest that an oil spill has killed sufficient fish to affect the viability of the adult population (IPIECA 1997).

Potential impacts to fish resulting from a hydrocarbon spill are considered minor given that fish mortalities are rarely observed to occur in such circumstances. This is because pelagic fish species are likely to detect and avoid water underneath hydrocarbon spills by swimming away from the affected area. Where hydrocarbon spills have occurred, impacts to fish are associated with areas where the effectiveness of natural dispersion mechanisms is limited. Such areas would be extremely localised, such as rock ponds and sheltered embayments.

Sea Snakes

Information relating to the susceptibility or sensitivity of sea snakes to hydrocarbon spills is very limited. Potential impacts may include toxicity effects caused by feeding on contaminated fish. In addition, sea snakes surface frequently to breathe and bask in the sun, making them susceptible to coating of respiratory apparatus from potential surface slicks.

Potential impacts resulting from a medium sized hydrocarbon spill are considered moderate. Impacts resulting from a small spill are considered minor, due to the short lived nature of surface slicks. It is also anticipated that sea snakes will demonstrate avoidance behaviour when they come into contact with hydrocarbons floating on the water surface.

Sea Turtles

Very little information is publicly available that documents the effects of hydrocarbon exposure on sea turtles, although spilled hydrocarbons have the potential to affect all life stages of sea turtles, both in the water or whilst nesting on the beach (Shigenaka 2003). Impacts may be direct or indirect, physical or toxic. Physical impacts include coating of the turtles, the nesting beach or their food sources, and ingestion of hydrocarbons may be toxic to both the adults and to the hatchlings. Other potential effects include irritation caused by contact with the eyes, nasal and other body cavities, and possibly ingestion or inhalation of toxic vapours. Hydrocarbons soaking into a nesting beach may directly impact on the development of embryos; however, the likelihood of slicks stranding or penetrating above the high tide level, where eggs are laid, is remote.

The Dampier Archipelago contains important turtle aggregation sites, particularly in the waters surrounding locations such as Rosemary Island, Malus Island, Enderby Island, Eaglehawk Island, Legendre Island and Delambre Island (CALM 2005). Limited nesting also occurs on the beaches at West Intercourse Island and at Holden Point (near to Site A). In the unlikely event of a hydrocarbon spill turtles either nesting on the beach or swimming in the water may be impacted. Small and medium sized spills are likely to result in moderate impacts.

Seabirds

Seabirds are highly susceptible to hydrocarbon spills, given that they spend large amounts of time on the sea surface, dive when disturbed and have relatively low reproductive rates (USEPA 1999). Birds that come into contact with hydrocarbon surface slicks may get their feathers coated and lose their ability to remain waterproof and retain their buoyancy above the water, and may subsequently suffer from hypothermia or mortality caused by drowning. They may also ingest hydrocarbons while attempting to clean their feathers or similarly when they ingest contaminated food, resulting in damage to internal organs, with lethal or sub-lethal effects (Piatt et al. 1990).

A number of seabird species have long lives, delayed maturity and low rates of reproduction, factors that can combine to restrict the recovery of populations following a mass mortality event, such as a large hydrocarbon spill (Lance et al. 2001). In particular, seabird species that have a limited distribution, isolated colonies and which are unlikely to colonise new habitats are most sensitive to the effects of hydrocarbon spills.

The Dampier Archipelago provides habitat for a range of seabird species including wedge-tailed shearwater (*Puffinus pacificus*), Caspian tern (*Sterna caspia*) and fairy tern (*Sterna neireis*), silver gulls (*Larus novaehollandiae*), crested terns (*Sterna cristata*), roseate terns (*Sterna dougalli*) and bridled terns (*Sterna anaethetus*). These along with other seabird species occurring in the area may be severely impacted from a surface spill of hydrocarbons through contact with the surface (for instance paddling and diving for prey). A small to medium sized hydrocarbon spill is unlikely to persist long enough in the marine environment or reach sensitive receptors to result in large scale seabird mortality. Potential impacts from these lesser sized events are considered moderate.

Dugongs

There is no available information that documents the susceptibility or sensitivity of dugongs to hydrocarbon spills. Dugongs may however be affected by ingestion of hydrocarbons while they are breathing on the surface and through irritation of the eyes. As with most animals, juveniles are most at risk. Longer term chronic effects may also be experienced when migrating through hydrocarbon contaminated waters. In addition, dugongs suffer secondary affects from the hydrocarbon spill through habitat disturbance and damage particularly to seagrass habitats.

Small or medium spills are likely to result in minor impacts as dugongs are likely to avoid surface slicks.

Whales and Dolphins

Whales and dolphins surface to breathe, at which point they may inhale hydrocarbon fumes which have the potential to cause lung injuries (USEPA 1999). They may also inhale hydrocarbons directly, resulting in toxicity effects, particularly from the lighter fractions, and may also experience eye irritations.

Whales and dolphins are smoothed skinned, hairless mammals and as such hydrocarbons tend not to adhere to their skin. They are therefore unlikely to be sensitive to the physical effects of hydrocarbon spills. Dispersed hydrocarbons are unlikely to cause any harmful effects to whales or dolphins due to their low toxicity, the limited period of potential exposure and the low dosage of hydrocarbons that may occur.

It is anticipated that whales and dolphins will exhibit avoidance behaviour patterns when in close proximity to a surface slick. Studies of bottlenose dolphins which are found within the Dampier Archipelago and wider region, showed that this species is able to detect and actively avoid a surface slick after a few brief contacts, with no observed adverse effects (Smith et al. 1983).

A number of whale and dolphin species are likely to occur within the Pluto LNG Development area. The Dampier Archipelago is not a recognised resting area for migrating whales, but whales do migrate steadily through the area (Jenner and Jenner 1991). Potential impacts of a hydrocarbon spill within the Archipelago are likely to be more severe to whales and dolphins than spills in the open ocean, where avoidance will be easier. In the unlikely event of a large hydrocarbon spill, the potential impacts to whales and dolphins are considered minor, given that there have been no reported effects on these species following such large spills.

7.10.6.2 Preventative and Management Measures

Spill Prevention Measures

A number of engineering measures will be implemented to prevent hydrocarbon spills from occurring during operations. All facilities will be designed and maintained in compliance with legislative requirements including P(SL)A, MARPOL 73/78, industry standards and will meet cyclone design standards. They will also be gazetted and marked on navigational charts and equipped with appropriate navigational lighting and radar reflectors. Proposed facilities within the Dampier Archipelago (navigation channel, jetty and off-loading facility) will meet Australian Maritime Safety Authority (AMSA) and DPA requirements for vessel safety. The specific measures to be implemented as part of the Pluto LNG Development Oil Spill Contingency Plan (OSCP) are summarised in **Table 7-38** and outlined further below.

Marine Vessel Refuelling (Construction and Operation): Hydrocarbon spill modelling has demonstrated that a small spill of diesel into the marine environment has the same potential to affect environmental receptors within the Dampier Archipelago as an equivalent sized spill of condensate (leak of gas trunkline). This is due mainly to the different physical properties affecting weathering rates. All Development-related vessels including dredge vessels, pipelay vessels, drill and blast rig and support and supply vessels will be subject to the following measures:

- Where practicable, re-fuelling for vessels operating within Dampier Archipelago will be undertaken in port, where spill risk factors can be more easily controlled.
- Re-fuelling at sea will only be undertaken during daylight hours except when compromised by safety considerations.
- Hoses, couplings and the sea surface will be visually monitored during re-fuelling operations.
- Tank levels will be continually monitored during re-fuelling to prevent overflow.
- Radio contact will be maintained between vessels during re-fuelling operations.
- 'Dry break' or 'breakaway' couplings will be used where available and practicable.
- All vessels will be required to have in place a Ship-Board Oil Pollution Emergency Plan (SOPEP) which includes oil spill response measures.
- Re-fuelling will only be undertaken when sea conditions are sufficiently calm, as determined by the master of the vessel and drill rig involved in the re-fuelling procedure.
- Responsibilities and accountabilities will be defined for response and notifications to Woodside and relevant authorities.

Gas Trunkline (Construction, Commissioning and Operation): The following design practices will be in place to minimise the risk of failure associated with the gas trunkline:

- the application of design codes and material specification to appropriate Australian and international standards
- the routine x-ray or ultrasonic inspection of welded joints and hydrostatic pressure testing prior to commissioning
- the provision of external corrosion protection
- trunkline stabilisation including concrete coating, trunkline trenching and burial in nearshore waters, rock berm protection in high risk areas as determined by Quantitative Risk Assessment and engineering studies, exclusion zones and pilotage requirements
- monitoring of the gas trunkline including monitoring of trunkline corrosion and corrosion protection system, periodic inspections by side scan sonar, ROV, post cyclone inspections if design environmental conditions are reached, periodic intelligent pigging operations in accordance with a risk based inspection philosophy and engineering assessments of trunkline service history
- the detection of trunkline ruptures primarily by instrumentation at the offshore platform and at the onshore processing plant, supplemented by observations (ROV, helicopter overflights etc.).

The LNG and Condensate Export Tanker Loading (Operations): The off-loading facilities and jetty will be visited by LNG tankers once every five days, and once every three months by condensate tankers. Hydrocarbon spills may potentially occur during vessel approach, mooring operations, product loading and during vessel departure. The following measures will be implemented:

- all LNG and condensate tankers will be MARPOL 73/78 compliant and vetted by Woodside
- a 24 hour CCTV and watch will be maintained during loading operations
- experienced pilots, with extensive local experience of Dampier Archipelago waters, and with previous experience in tanker loading operations, will moor the trading tankers
- loading of LNG and condensate will only occur if weather conditions are suitable

- the LNG and condensate pressurised load-out facilities will be equipped with 'dry break' couplings
- all valves and transfer lines will be checked for integrity prior to use and loading operations will be continually monitored
- emergency shutdown valves will be triggered in the event that a leak of the load-out lines occurs
- emergency response procedures will be activated.

Drilling and Subsea Infrastructure (Construction and Operation): The following measures will be employed during drilling activities and operation of the subsea wells, manifolds and flowlines:

- standard drilling practices and equipment will be used to drill the wells
- well blow-out preventors will be in place for each well, in accordance with regulatory requirements and industry standards. Well blow-out preventors will be capable of withstanding pressures well in excess of those likely to be encountered during drilling
- the adoption of high integrity design
- subsea systems will be integrity tested and regularly inspected by ROV flyovers.

Oil Spill Contingency Planning

The probability of a large hydrocarbon spill occurring from the Pluto LNG Development is remote. The main preventative measure employed to reduce the risk of potential environmental impacts, should such an event occur, will be the implementation of an OSCP.

Drilling and construction activities will be carried out either under the umbrella of Woodside's own regional Western Australia and Dampier Sub-Basin OSCP, which includes a detailed OSCP that has been submitted to, and accepted by DoIR, under requirements of the P(SL)A or a stand-alone document which will similarly require approval by DoIR.

For the operational aspects of the Development, two options are being considered for the OSCP, these being:

1) Tie-in to the existing Woodside regional OSCP, which already has government acceptance thereby utilising existing procedures and equipment which will need to be supplemented.
2) Prepare a specific Pluto LNG Development OSCP.

Regardless of the option chosen the OSCP will:

- ensure the effective and timely management of hydrocarbon spills
- describe the procedures to deal with an oil spill
- define the roles and responsibilities of response personnel
- describe the external resources available for use in combating oil spills and how these resources will be coordinated
- be integrated with existing state government, Commonwealth and industry response plans
- be separately assessed by DoIR under the P(SL)A and must be accepted prior to commencement of operations.

The plan will be updated periodically (as required by P(SL)A)) to address specific actions in the event of potential spills from:

- vessels
- fuel transfers
- tanker loadings
- production facilities
- gas trunkline loss of containment.

Should a hydrocarbon spill occur within DPA waters, the DPA OSCP will apply. The Woodside regional OSCP or Pluto LNG Development OSCP will tie into the DPA OSCP for responses within DPA waters.

In the unlikely event of a hydrocarbon spill that is beyond the response capability of Woodside, a request will be made for the activation of the State Plan or National Plan to 'Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances' (or within DPA limits, the DPA Plan). Support for oil spill response and management is available from other oil and gas operators in the region under a Mutual Aid Agreement and within 24 hours of notification from the industry sponsored Australian Marine Oil Spill Centre (AMOSC) based in Victoria.

Additional Considerations and Spill Response Times

The OSCP will be updated to reflect the results and outputs of the hydrocarbon spill modelling. It will also include the results of toxicity testing of Pluto condensate and testing of the effectiveness of dispersant and containment measures on Pluto condensate.

The modelling will be pivotal in influencing response times for various spill scenarios. For example, a spill of condensate at the jetty during pipeline load-out is predicted to make contact with the shoreline at Holden Point in less than 30 minutes from the release time (**Section 7.10.5**). For this scenario, it is therefore possible that impacts to the shoreline may occur before a response can be mounted. In contrast, it is predicted that spilled condensate from a rupture of the gas trunkline would take approximately 1–4 hours to reach the shorelines of islands in the Dampier Archipelago, depending on the season. The response time in any given case would ultimately depend upon the distance from the oil spill response base, whether the spill is ongoing and if safety requirements prevent vessels from directly engaging the spilled hydrocarbons.

Table 7-38 Summary of Impacts, Management and Risks of Hydrocarbon Spills

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Marine biodiversity	Large size condensate spill from rupture of the export trunkline (1200 m^3)	Plankton	The risk of a large hydrocarbon spill occurring is highly unlikely. A range of preventative, management and spill response measures will be in place to prevent spills from occurring. An OSCP will be developed and implemented. The plan will: • ensure effective and timely management of spills of hydrocarbons • describe the procedures to deal with an oil spill • define the roles, responsibilities of response personnel • describe the external resources available for use in combating oil spills and how these resources will be coordinated • be integrated with existing State government, Commonwealth and industry response plans • be separately assessed by DoIR under the P(SL)A and must be accepted prior to commencement of operations. Measures will be implemented with respect to: • marine vessel re-fuelling • construction, commissioning and operation of the gas trunkline • LNG and condensate export tanker loading during operations • drilling and subsea infrastructure. Should a hydrocarbon spill occur within DPA waters, the DPA OSCP will apply. The Woodside Western Australia and Dampier Sub-Basin OSCP or Pluto LNG Development OSCP will tie into the DPA OSCP for responses within DPA waters.	D	1	L
		Algae		D	1	L
		Seagrass		C	1	M
		Mangroves		B	1	M
		Rocky shore habitat		D	1	L
		Coral reef		C	1	M
		Fish		C	1	M
		Sea snakes		D	1	L
		Sea turtles		B	1	M
		Seabirds		B	1	M
		Dugongs		C	1	M
		Whales and dolphins		C	1	M
	Medium size condensate spill from failure of off-loading pipeline during export tanker loading in Dampier Archipelago (566 m^3)	Plankton		D	1	L
		Algae		D	1	L
		Seagrass		D	1	L
		Mangroves		B	1	M
		Rocky shore habitat		E	1	L
		Coral reef		C	1	M
		Fish		E	1	L
		Sea snakes		E	1	L
		Sea turtles		D	1	L
		Seabirds		C	1	M
		Dugongs		C	1	M
		Whales and dolphins		D	1	L
	Small diesel spill from re-fuelling accident in Dampier Archipelago (2.5 m^3) / pipeline leak in Mermaid Sound (2.16 m^3)/ failure of condensate load-out pipeline – dry break coupling activated (10 m^3)	Plankton		E	2	L
		Algae		E	2	L
		Seagrass		E	2	L
		Mangroves		D	2	M
		Rocky shore habitat		E	2	L
		Coral reef		E	2	L
		Fish		E	2	L
		Sea snakes		E	2	L
		Sea turtles		E	2	L
		Seabirds		D	2	M
		Dugongs		E	2	L
		Whales and dolphins		E	2	L

7.10.6.3 Residual Risks

The residual risk of potential environmental impacts to various environmental receptors and sensitivities resulting from a hydrocarbon spill will very much depend on the size of the spill, the weathering characteristics of the condensate and diesel, time of year and proximity of the release site in relation to the shoreline.

Although such an occurrence is unlikely, there is residual risk of impacts resulting from a large sized condensate spill, for example a trunkline rupture of 1200 m^3 condensate. Residual risk exists due to the proximity of sensitive receptors adjacent to potential spill sites, particularly within the Dampier Archipelago. Large spills are predicted to reach shorelines within 1–4 hours, during which time it may be difficult to mount an effective response, especially if strong wind, tidal and wave forces are experienced. Species considered to be at 'medium residual risk' either because of their sensitivity to disturbance, proximity to spill sites or protected status include sea turtles (either nesting or swimming), mangroves, corals, seabirds seagrass, fish, dugongs, whales and dolphins. All other species and habitats (plankton, algae, rocky shore habitat and sea snakes) are considered to be at low residual risk.

The residual risk of impacts to mangroves occurring from a medium sized spill at the jetty and loading facilities remains medium. This is because mangroves occur in close proximity to the loading jetty and spill modelling has demonstrated that shoreline contact from a spill of this nature would be made in less than 30 minutes from the release time. Residual risks to all other species are considered to be either medium or low.

A small sized spill, such as a diesel refuelling accident is likely to result in either medium or low residual risks. Species that are considered to be at medium residual risk from impacts include mangroves, sea turtles and seabirds. All other species are considered to be at low residual risk of impact.

7.11 Noise

Potential Impacts

There are a number of activities within the Dampier Archipelago that result in subsea noise emissions that are elevated above background levels. The DPA is Australia's second largest port, accommodating a range of vessel types and sizes. Key emission sources in the vicinity include a number of NWSV LNG and LPG tankers, the Hamersley Iron ore bulk carriers, Dampier Salt carriers, commercial ships docking at the DPA, and recreational vessels. There is limited vessel activity within the Pluto gas field (**Figure 10-15**).

Potential sources of noise associated with the construction and operation of the Pluto LNG Development include:

Construction Related

- drilling rig
- pipe-lay barges
- dredging vessels
- support and installation vessels (including propeller noise)
- drill and blast rig
- piling from jetty construction
- spoil disposal from dredging activities
- blasting.

Construction and Operations Related

- support and supply vessels
- helicopter activities.

Sources and levels of noise emissions are discussed in more detail in **Section 5.1.7**. Noise levels from literary reviews, for the sources listed above, range from 154 dB re 1µPa at 1 m to 198 dB re 1µPa at 1 m (Richardson et al. 1995); whereas naturally occurring noise levels in the ocean as a result of wind and wave action may range from around 90 dB re 1µPa under very calm, low winds to 110 dB re 1µPa under windy conditions. However, with the current commercial and recreational shipping activities in the Dampier Archipelago background noise levels are probably higher.

Impacts from helicopter noise generations will be highly dependent on its angle and distance above the sea surface. Impacts are expected to be minimal.

Noise emissions can potentially have the following non-physiological adverse effects on marine fauna:

- attraction to the source of noise
- increased stress levels
- disruption to underwater acoustic cues
- behavioural changes
- localised avoidance
- secondary ecological effects; a 'domino effect' whereby an effect on a particular species is felt through the ecosystem.

Noise attenuates with increasing distance from the source and consequently the impacts from noise emissions are diminished further away from the source. Conversely, fauna will often approach or remain near to a noise source, such as an operating facility, even though the level of noise exceeds that at which behavioural changes have been observed to occur even if there is no corresponding threat associated with the noise.

Marine Mammals

Marine mammals that can be tested have an extremely acute acoustic sense and are correspondingly sensitive to sounds below and, to a lesser extent, above the water surface. Noise generated during the construction and operational phases of the Development may interfere with the acoustic perception and communication of any marine mammals in the vicinity, and may have the potential to induce stress should it exceed some threshold level. The threshold noise level for behavioural changes may vary for different species, different individuals and even the same individual in different behavioural states. Some species, such as dolphins and humpback whales, are known to frequently approach vessels and production facilities.

Humpback whales may migrate through the development area, and a number of other dolphins and whales could potentially be present in the vicinity of the Development. Blue whales are known to be present in the vicinity of the Development.

Richardson et al. (1995) presented summary tables of the broadband levels at which several species of whales exhibited avoidance behaviour, indicating that such behaviour occurs at broadband noise levels of approximately 114–131 dB re 1μPa. This is consistent with a study of the response of humpback whales to noise generated by vessels (McCauley et al. 1998) that observed behavioural changes when humpback whales are exposed to continual broadband noise levels in excess of 115db re 1μPa.

Noise emissions from the Pluto LNG Development during construction are predicted to be approximately 154–198 dB re 1μPa at 1 m.

Broadband noise levels vary greatly with each species of whale; for example, the source levels of the highest components of humpback whale song are 192 dB re 1 Pa2, which is above the levels generated by drilling and support vessels (McCauley 1994), suggesting that noise generated by drilling may not have a significant impact on this particular species.

Dolphins receiving noise levels above 120 dB re 1μPa-m showed no significant reactions in a 1991 study (Richardson et al. 1995). Dolphins have high frequency hearing whereas the construction equipment produces noise at lower frequencies, and so are not likely to be impacted upon.

Baleen whales in the open waters are predicted to avoid a localised area centred on the drilling rig and platform during construction when noise levels are at their highest. It is unlikely that toothed whales and dolphins would be negatively affected by underwater noise associated with construction or operation activities offshore.

Sea Turtles

The green turtle, hawksbill turtle, flatback turtle and loggerhead turtle occur in the Pluto LNG Development area and all are recorded as nesting on sandy beaches found in the region. Electro-physical studies have indicated that the best hearing range for sea turtles is in the range of 100–700 Hz, however no definitive thresholds are known for the sensitivity to underwater sounds or the levels required to cause pathological damage (McCauley 1994). Sea turtles are also expected to avoid areas before sounds reach a level where it can cause them any physical harm.

Fish

The levels of noise generated during the proposed Pluto LNG Development may cause behavioural changes or mask other acoustic cues necessary for normal biological/ecological functioning. A considerable body of fisheries literature exists on the behavioural response of fish to the noise of approaching vessels (for example, Olsen 1990), and these studies have shown that fish do avoid approaching vessels to some degree, usually by swimming down or horizontally away from the vessel path. The degree of observed effect weakens with depth, with fish below about 200 m depth being only mildly affected, and the effect is temporary, with normal schooling patterns resuming shortly after the noise source has passed.

Surface and mid-water dwelling fish may theoretically be adversely affected by noise generated during vessel movements and normal production operations; however, some studies (for example. Rostad et al. 2006) have found the relationship between fish and vessel noise is more complex than previously anticipated with many fishes being attracted to vessel noise. In any event, the obvious abundant presence of fish that accumulate adjacent to existing operating facilities and shipping vessels in and around the Dampier Archipelago indicate that they are able to habituate to these noises with no apparent detriment.

Seabirds

Seabirds are generally unlikely to be directly affected by underwater noise generated during the proposed Development. Seabirds may potentially be at risk from scavenging on dead fish within the marine blasting zone.

Given that it is not expected that fish and other prey species will be significantly impacted, nor is the area noted as being of special importance for seabird feeding, it is also highly unlikely that seabirds would be secondarily affected by underwater noise.

Preventative and Management Measures

Proposed management measures are summarised in **Table 7-39**.

Residual Risks

Residual risks are considered low.

Table 7-39 Summary of Impacts, Management and Risks of Noise

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Noise and Vibration	Construction equipment Construction and operation vessels operating in nearshore and offshore waters Helicopter operations between mainland and offshore platform	Disturbance to marine fauna including seabirds Disturbance to EPBC Act listed species and sensitive seasons / locations	Equipment will be designed to normal petroleum practice, which includes specifications for noise levels, and standard installation and drilling facilities will be used. The interaction of construction and operation vessels and helicopters with cetaceans will be consistent with Part 8 of the EPBC Regulations 2000.	D	1	L

7.12 Marine Blasting

Potential Impacts

Shock waves associated with underwater blasting can potentially cause impacts to marine fauna including behavioural changes, physical injury and death (if they are within a close range). Impacts on marine fauna from blasting activities will depend on the size of the charge, the composition of the explosive, water depth, the distance from the explosion centre, and the size and type of species.

Estimates of lethal ranges and safe distances for fish and other marine animals can be determined using a technique determined by the Canadian Department of Fisheries (CDF), or by a method developed by ICI Australia (ECOS Consulting 1996). The CDF technique takes into account animal weight and target depth and may be considered to be more accurate. There are, however, many other variables including, size, species physiology, orientation of the animal to the shock wave and bottom type, which make either method at best only a general indicator of safe and lethal ranges.

Marine Mammals

The principal effects of explosives for marine mammals concern damage to the lungs. In some instances, whilst charges may not be sufficient to cause death, there may be sub-lethal damage to auditory systems (for example, ruptured ear drums).

Table 7-40 provides estimates of effect ranges calculated using the CDF technique for marine mammals diving beneath the surface from a generalised marine blasting operation in Mermaid Sound. Basic assumptions for the calculations are that the mammals are near bottom, water depth is 10 m, and the blast weight is 78 kg.

Sea Turtles

No specific information is available on the risk to marine reptiles from marine blasting. In the absence of data they are conservatively assumed to have similar physiological risk as mammals. Blasting is likely to cause temporary disturbance and avoidance effects in turtles that are present in the vicinity of the blasting activities.

Fish

Fish mortality from blasting is predominantly caused by rupture of the swim bladder. Larval fish are less sensitive to the effects of shock waves than eggs or post larval fish in which a swim bladder has developed (ECOS Consulting 1996). Spiral curling of the embryo and disruption/deformation of egg membranes has also been observed for fish species as a result of small (50 gm) charges of TNT (WBM Oceanics 1993).

Table 7-41 shows effect ranges calculated using the CDF technique for 10 kg fish from a generalised marine blasting operation in Mermaid Sound. Basic assumptions for the calculations are that the fish are demersal, water depth is 10 m, and the blast weight is 78 kg. The estimated mortality ranges would appear to be conservative given the findings from a study conducted by McAnuff and Booren (1989) on caged fish. The study estimated probable 100% and 10-20% fatality radii, using charge weights of up to 270 kg, as 20-50 m and 45-110 m respectively.

Seabirds

Birds most at risk from marine blasting are diving species. No specific information is available on the risk to seabirds from marine blasting. In the absence of data they are conservatively assumed, when diving, to have similar physiological risk as mammals.

Preventative and Management Measures

Proposed management measures are summarised in **Table 7-42.**

Residual Risks

The residual risks are considered medium.

Table 7-40 Estimates of Blast Effect Zones Calculated for Marine Mammals (78 kg Confined Charge Marine Explosion in 10 m Water Depth) Distance Effects

Distance	Effects
0 m–387 m	No mortality. High incidence of moderately severe blast injuries, including eardrum rupture. Animals should recover.
387 m–645 m	High incidence of slight blast injuries, including eardrum rupture. Animals should recover.
645 m–1075 m	Low incidence of trivial blast injuries. No ear drum ruptures.
1075 m	Safe level. No injuries.

Source WEL 1997

Table 7-41 Estimated Blast Effect Zones for 10 kg Marine Fish (demersal fish from a 78 kg confined charge marine explosion in 10 m water depth)

Distance	Effects
0 m–215 m	50 % Mortality
215 m–301 m	1 % Mortality
>301 m	Safe level. No injuries.

Table 7-42 Summary of Impacts, Management and Risks of Marine Blasting

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Marine Blasting	Shock and sound waves from blasting during construction	Behavioural changes, injury or mortality to marine mammals, sea turtles, fish and diving seabirds	Development and implementation of a Blasting Management Plan (**Table G-7**, **Appendix G**) that will include the following measures: • Smaller, more frequent blasts will be planned using sequential explosive charges to minimise cumulative impacts of the explosions. • Marine fauna activities will be taken into consideration when blasting, drilling and/or dredging, especially during sensitive periods for the fauna. • Procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence. To minimise injury to seabird species dead fish on the surface of the water after a blast will be collected to prevent bird injuries or mortality from successive blasts.	D	3	M

Existing Terrestrial Environment 8

8.1 Studies and Surveys

Studies and field surveys were undertaken to provide site-specific terrestrial baseline information for this Draft PER. While the receiving environment associated with much of the study area is relatively well understood, detailed knowledge of some specific areas was limited. All studies and field surveys have used approved methodologies and approaches to satisfy EPA regulatory requirements and guidelines. Literature reviews and searches of key data sources including the Western Australian Museum and CALM (now the DEC) databases were also conducted.

The key studies undertaken include:

- a flora and vegetation condition assessment of gas trunkline Option 1, undertaken by ENV in 2006
- a vegetation and flora survey of Site B South by Astron Environmental in 2005 on behalf of a previous proponent of this site, Agrium Australia Pty Ltd
- a vegetation and flora survey of Site B North was undertaken by ENV Australia in 2006
- a vegetation and flora survey of Site A was undertaken by Astron Environmental in 2005
- a desktop fauna study for the Pluto LNG Development area was undertaken by Worley Astron in 2005
- a land snail survey for Site A was undertaken by the Western Australian Museum in 2005
- wet season land and aquatic snail surveys were undertaken for Site B and Site A by Biota in 2006.

Due to significant rainfall in the region, the vegetation and flora surveys undertaken provided a good representation of vegetation and identified a large range of flora.

8.2 Physical Terrestrial Environment

8.2.1 Climate and Meteorology

The climate of the Burrup Peninsula and its surrounds comprises two distinct seasons: a hot wet summer with periodic, heavy rains; and a mild winter with occasional rainfalls. The Koppen climate classification system categorises the Burrup Peninsula as having an arid tropical desert zone climate with mainly summer rainfall. The three specific weather phenomena that are of greatest importance to the region are (SKM 2001):

- tropical cyclones frequently accompanied by damaging winds, storm surge and flooding
- strong easterly winds from May to September caused by the development and intensification of anti-cyclones over southern Western Australia or South Australia
- major cloud bands that develop and extend from the north-west coast, across the continent, bringing rain to the north-west and the interior of the country.

Long-term meteorological data (including rainfall, temperature, humidity and wind speed and direction) has been recorded by the Bureau of Metereology (BOM) since 1969 at the Dampier Salt operations, the BOM weather station nearest to the Development area (BOM 2005). A summary of this meteorological data for the period 1969–2004 is presented in **Table 8-1**.

Air Temperature and Humidity

The hot wet summer season for Dampier and Karratha occurs from October to April followed by the mild winter season from May to September. Monthly mean maximum temperatures range from 26.1°C in July to 36.2°C in March. The monthly mean minimum temperatures range from 13.4°C in July to 26.5°C in February.

Rainfall and Evaporation

The Pilbara region of Western Australia has a highly variable rainfall, and is strongly influenced by tropical cyclone activity during the summer months. Rainfall is also often erratic and very localised due to thunderstorm activity, and monthly average rainfalls can vary dramatically from year-to-year. The first rainfall peak of the year occurs between January to March as a result of tropical thunderstorms and cyclonic activity, with a second peak occurring between May and June due to the passage of low pressure systems through the south of Western Australia.

Table 8-1 Summary of Climate Averages for Dampier/Karratha from 1969–2004

Month	Temperature (°C)	Mean Rainfall (mm)	Mean 9am Relative Humidity (%)	Mean 3pm Relative Humidity (%)	Mean Daily Evaporation (mm)	Wind Speed (km/hr)	
						Mean 9am Windspeed	Mean 3pm Windspeed
January	35.9	27.1	58	51	11.3	15.7	27.6
February	36.1	64.0	60	51	10.4	15.5	26.4
March	36.2	46.4	54	44	10.3	14.4	23.7
April	34.4	20.1	45	37	9.3	15.3	22.4
May	29.9	26.6	45	38	7.2	17.8	20.7
June	26.6	35.0	47	40	6.1	18.0	20.6
July	26.1	13.4	44	36	6.3	17.1	20.1
August	27.7	5.8	43	35	7.3	15.8	21.5
September	30.5	1.3	37	33	9.2	16.8	24.5
October	32.6	0.4	39	37	10.9	16.6	28.2
November	34.3	0.4	41	41	11.9	16.6	29.2
December	35.7	12.5	49	44	11.9	16.6	28.8
Monthly Mean[1]	32.2	21.1	47	40	9.3	16.4	24.5
Annual Total[2]	–	260.6	–	–	3407.4	–	–

Note 1: Monthly means based on monthly averages
Note 2: Approximation based upon mean daily values within each monthly period
Source: Bureau of Meteorology 2005a

Wind

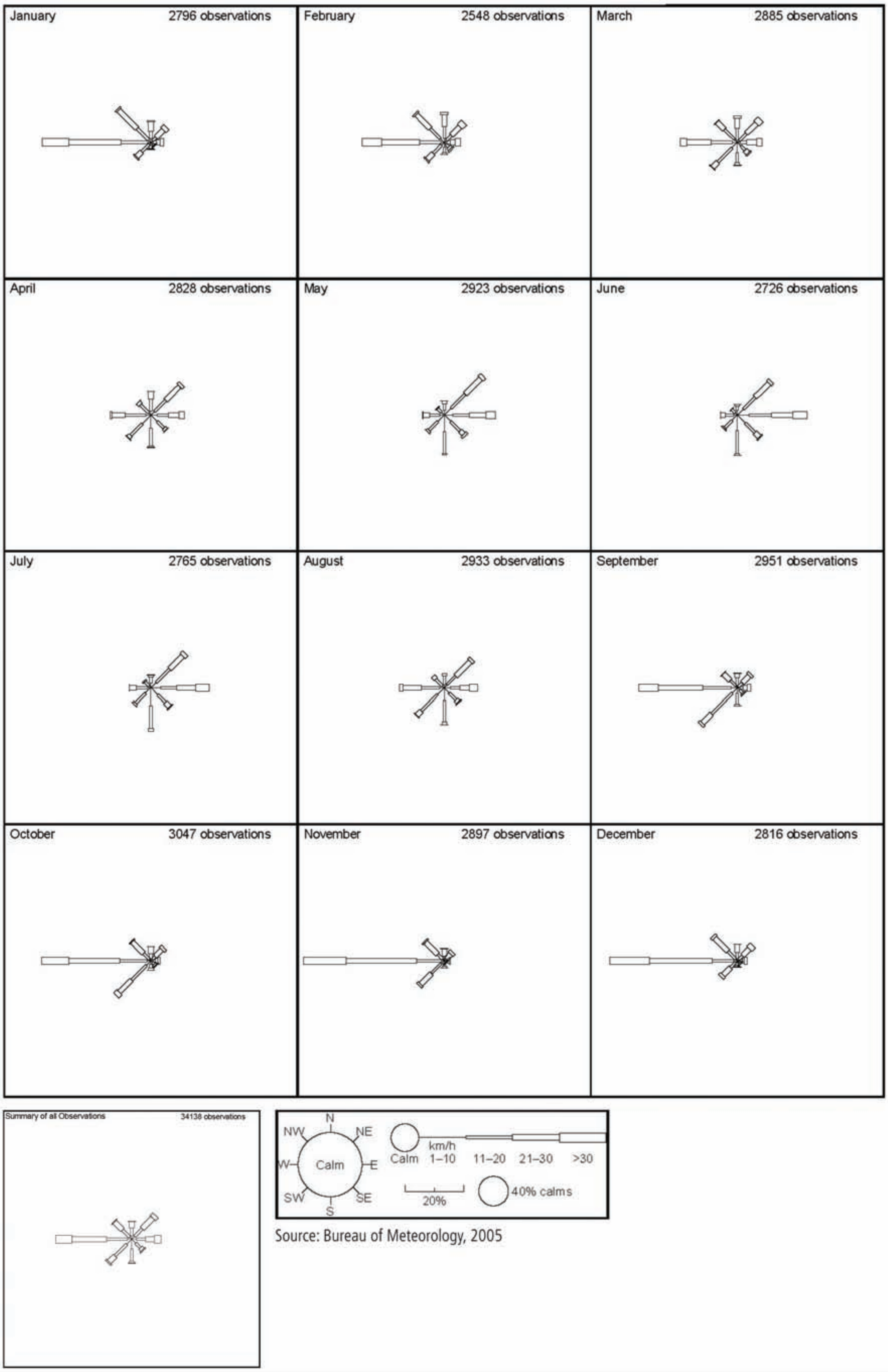
Winds during winter are predominantly easterlies, changing to westerlies during summer. During winter, east to south-easterly winds are dominant in the mornings and shift to north-easterlies in the afternoon before easing in the evening in response to diurnal land temperature changes. Average wind speeds range from 16.8 km/hr to 24.5 km/hr; however, maximum wind gusts from these directions can exceed 77.8 km/hr during storms generated by the interaction of high pressure belts and northern tropical low pressure systems (BOM 2005).

During the summer months, westerly winds are dominant in the morning, shifting to north-westerly onshore in the afternoon. Average wind speeds from these directions are 14.4 km/hr and 29.2 km/hr respectively, with an increase in speed from morning to afternoon. Maximum wind gusts of 63 km/hr and 57.6 km/hr have been recorded for April and November, respectively (BOM 2005). Wind roses for Karratha, which is located approximately 17 km from Site A, are shown in **Figure 8-1**.

Tropical Cyclones

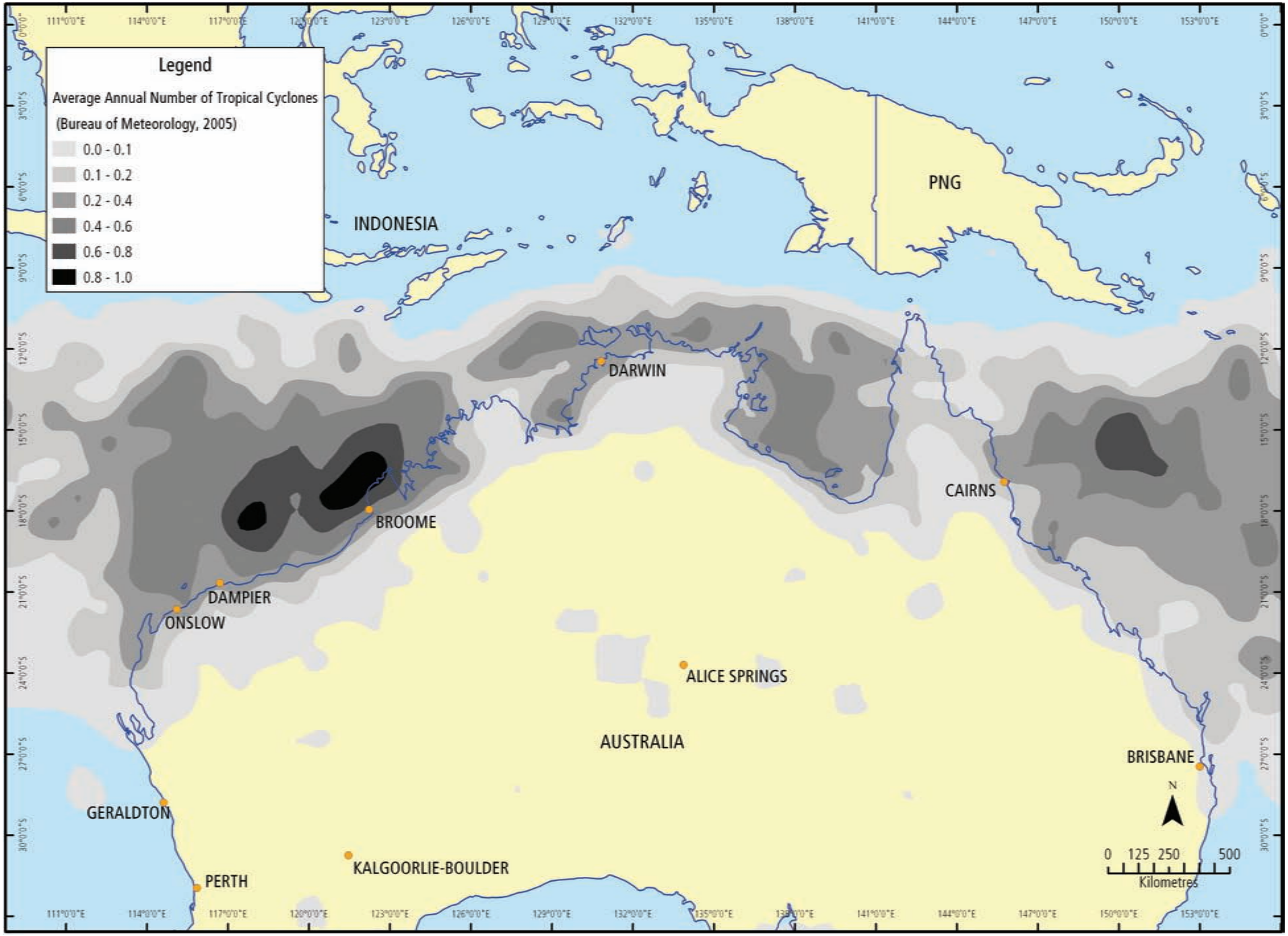
Tropical cyclones in the region generally form over the Indian Ocean and Timor Sea penetrating south into the Kimberley and Pilbara regions of Western Australia, making this the most cyclone-prone area in Australia. Tropical cyclone frequency for northern Australia is shown in **Figure 8-2**. The most active months for tropical cyclones in the Pilbara region are mid-December to April with an average frequency of two cyclones per year crossing the Pilbara coast, one of which is severe (BOM 2005). During cyclones, wind speeds are likely to reach up to 250 km/hr with heavy swells and torrential rain also occurring.

Figure 8-1 Monthly and Annual Wind Roses for Karratha



Source: Bureau of Meteorology, 2005

Figure 8-2 Tropical Cyclone Frequencies in Northern Australia



8.2.2 Landforms and Topography

On a regional level, the Burrup Peninsula and adjoining mainland fall within the Granitic Land System (**Figure 8-3**), as defined by Van Vreeswyk et al. (2004). This land system features sandy plains and rocky boulder landscape. The Development area reveals a generally rugged topography with deep linear gorges, rock escarpments, frequent rock outcrops, in addition to some relatively flat areas. Elevation rises from sea level at Holden Point peaking to approximately 80 m AHD at Site B (**Figure 8-4**). Along the eastern border of Site B the elevation gradually reduces (Dames and Moore 1998a).

Gas Trunkline Option 1

Gas trunkline Option 1 passes through relatively large areas of flat, pre-disturbed land located within the existing boundary of the NWSV Karratha Gas Plant. Along the southern section of the trunkline route, close to Site A, the topography increases in elevation from approximately 10 m AHD to 30 m AHD. In doing so, the trunkline will cross one of a series of dolerite dykes that transect the development area (**Section 8.2.3**).

Gas Trunkline Option 2

The gas trunkline Option 2 comes ashore at Holden Point, within Site A. It then travels through Site A in an easterly direction before crossing into Site B. As such, landform and topography information for the gas trunkline Option 2 corridor is included in Site A and Site B below.

Site B

The landforms at Site B are typical of much of the Burrup Peninsula, characterised by an abundance of loose boulder outcrops, parallel rock ridges, upland terraces and deep linear channels (Dames and Moore 1998a). The site contains a series of distinct rock escarpments that are positioned parallel to the coast and extend beyond the boundaries of Site B covering a large area of the Burrup Peninsula (Dames and Moore 1998a). The westward facing slopes of the escarpment are divided into a natural series of low angled benches and appear as surface expressions of banding that has occurred within the rhyodacite. The scale of the banding is highly variable, with non-outcrop areas ranging from tens of metres wide to more than 300 m wide close to the western boundary of Site B and near to the existing NWSV Haul Road. Where rocky outcrops occur, in numerous locations on the site, they are intensely fractured and are visible as distinctive piles of loose tabular or columnar blocks (Dames and Moore 1998a).

Site B has an elevation range of between approximately 30 to 80 m AHD and rises steeply from the southern and north–western boundaries of the site. Towards the centre of the site the topography is relatively flat and is characterised by rocks, small boulders and minor drainage lines. Three distinct drainage channels transect the site in a north–west to south–east direction each separated from the other drainage channels by up to 1 km. These channels represent dolerite dykes with alluvial covering and intersect the much harder rhyodacite rock. They are steeply-sided and are between 5–10 m in depth. Some smaller gullies intersect the larger channel at right angles and exhibit a north-east to south-west alignment. Much smaller linear features that do not exhibit significant topographical relief or width are recognisable from aerial photographs and are likely to be remnants of tensional fractures within the rhyodacite granite, which have not been intruded by dolerite (Dames and Moore 1998a).

Site A

Site A contains four major types of landform units including:

- rocky outcrops and scree slope terrain
- hilltop plains
- low coastal terrain (including alluvial fans)
- coastal fringe.

With the exception of the alluvial fans, these landforms are all erosional features. The topography of the site is graded towards the north-west, reaching approximately 30 m AHD in the eastern corner of the site. The higher elevations are primarily associated with rocky outcrops.

The coastal fringe is represented by a rocky granite headland (Holden Point) located in the north of the site, a beach and associated sand dunes that occupy the majority of the coastal fringe. Rhyodacite rock formations enclose the bay towards the south of the site. Within the southern area of Site A there is an 'amphitheatre-like' feature comprised of samphire, which has been formed over time by the erosion of several intersecting dykes (Dames and Moore 1998a).

Figure 8-3 Landforms and Soils of the Pluto LNG Development Area

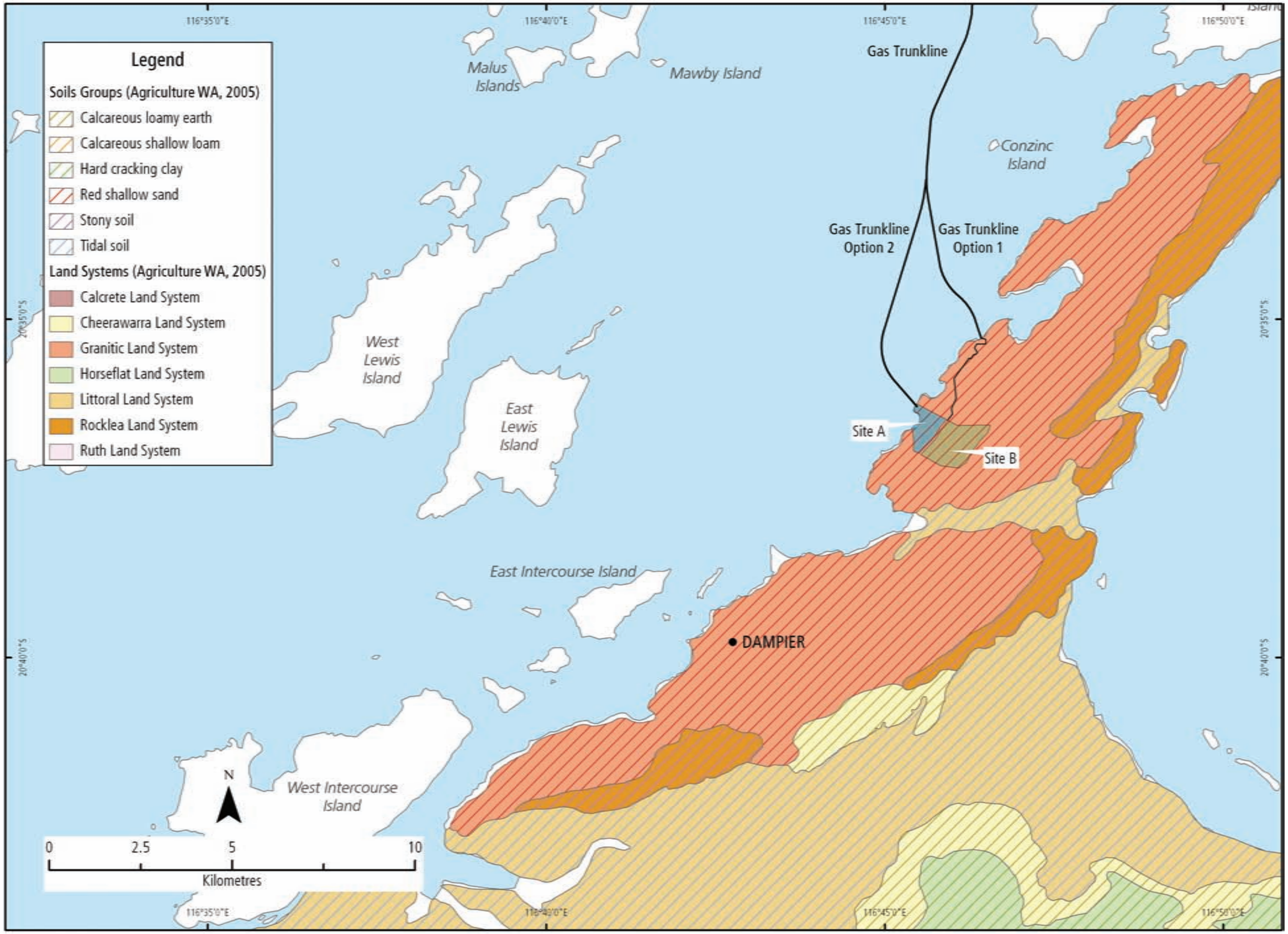
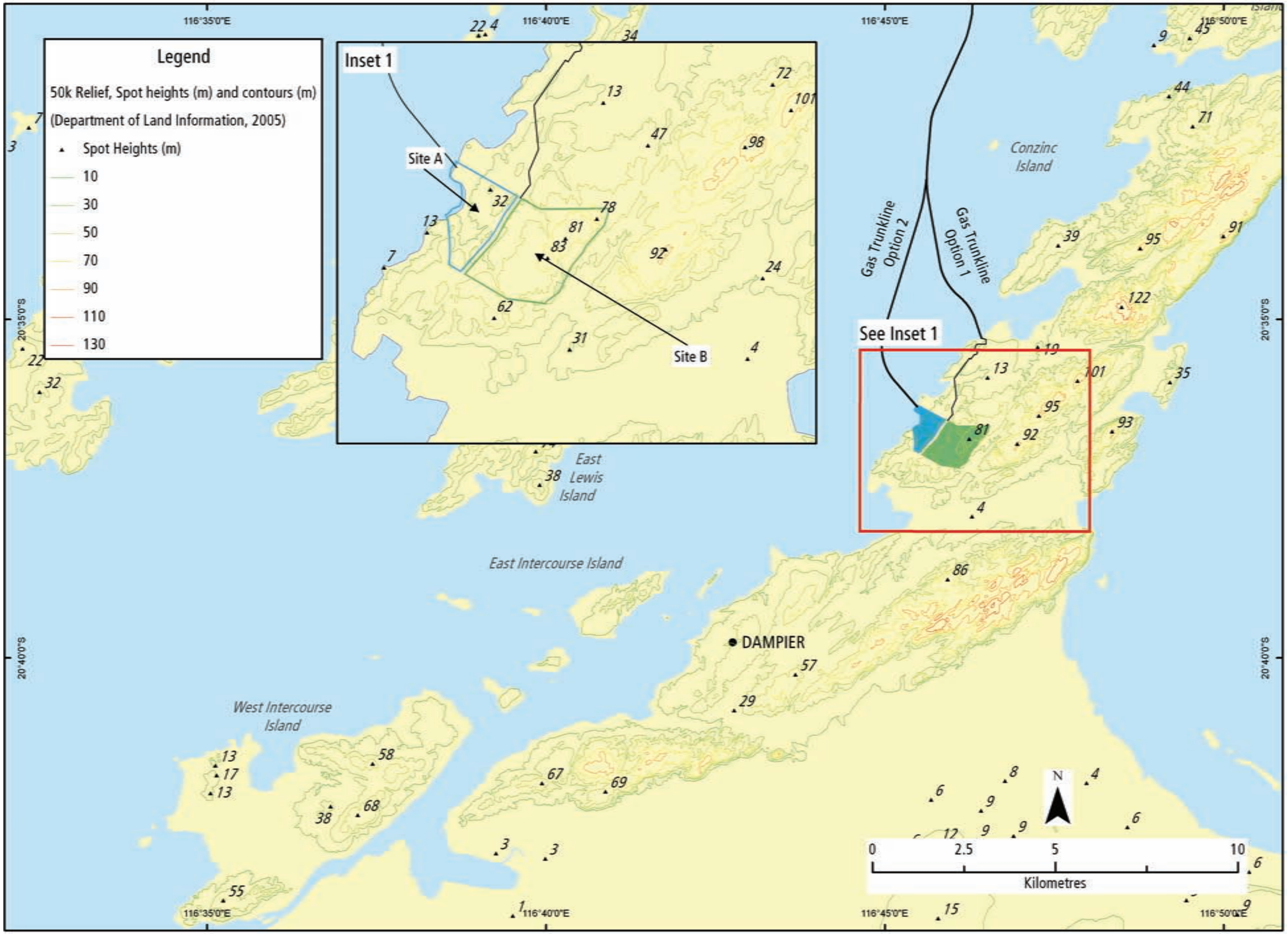


Figure 8-4 Topography of the Pluto LNG Development Area



8.2.3 Geology and Soils

8.2.3.1 Regional Geology and Soils

The Burrup Peninsula is part of a spine of Archaean igneous rocks that includes granophyres, gabbros and small granite exposures (DEC 2006). These rocks form the eastern part of the Dampier Archipelago and include Dolphin Island, Angel Island and Gidley Island. The western group of islands within the Archipelago are represented by ancient basalt, which also covers much of the Burrup Peninsula and are characterised by rockpile formations. The three principal geological units of the Burrup Peninsula are as follows (SKM 2002):

- The Gidley Granophyre which is Proterozoic in age and typically occurs as extensive outcrops or sub-outcrops on the Burrup Peninsula. The granophyre is a blue-grey rock typically with a reddish brown weathered surface and very high strength. It is fine to medium-grained and composed of equal amounts of quartz, pink feldspar, dark ferromagnesian laths and subordinate white feldspars.
- Colluvium which is a mixture of boulders, cobbles, gravels and silty sand, derived predominantly from the granophyre and the overlying soil. Coarse materials are generally located on the upper slopes with the finer materials located on the lower slopes.
- Alluvium that consists predominantly of silts and sand of estuarine and aeolian origin. Calcrete, calcareous conglomerate/conglomeratic calcarenite and calcareous soils may also occur. These are much younger geological units compared to the Granophyre units and are of Quaternary age.

Igneous dolerite dykes and gabbro, which are mainly comprised of pyroxene, are also a dominant feature of the landform in the Burrup Peninsula. In general, the dolerite is preferentially weathered compared to the granophyre which has resulted in a distinctive network of steep-sided linear gullies intersecting the basement rocks.

The Burrup Peninsula is heavily weathered and the red soils that exist on the Peninsula are relatively shallow, reaching a maximum depth of 2 m in the lower alluvial slopes (DEC 2006). In certain areas of the Burrup Peninsula, particularly in valleys, extensive stony clay colluvial infills have established over time. The low-lying coastal areas contain coarse sandy soils, in addition to saline mudflats located predominantly on the eastern side of the Burrup Peninsula.

8.2.3.2 Geology and Soils in the Development Area

Gas Trunkline Option 1

A significant length of the proposed gas trunkline Option 1 is located with the boundary of the existing NWSV Karratha Gas Plant and therefore lies within pre-disturbed land. The NWSV Karratha Gas Plant has been built on a raised fill platform which comprised the excavation of all topsoil, erosional deposits and the in-situ weathering profiles from the site to expose 'fresh' bedrock. The bedrock surface was subsequently used as the base on which the fill platform was constructed. The excavated material, together with material from local sources was used as fill. Typically this material consisted of coarse angular gravel, cobbles and boulders of granophyre debris. Whilst the depth of fill is variable, boreholes drilled within the platform by URS suggest that it ranges from 4–11.5 m depth (URS 2004c).

Along the southern section of the route close to Site B, the geology is dominated by granophyric rhyodacite rock.

Gas Trunkline Option 2

The gas trunkline Option 2 comes ashore at Site A, then travels through Site A in an easterly direction before crossing into Site B. As such, geology and soil information for the gas trunkline Option 2 corridor is included in Site A and Site B described in the following section.

Site B

The geology at Site B is dominated by Proterozoic-aged, Granophyric rhyodacite rock, intersected by dolerite dyke channels and an isolated area of granite outcrop. The Granophyric rhyodacite rocks are either blue-grey or purple-green in colour and fine to medium gained (Dames and Moore 1998b). As mentioned previously, the exposures of rhyodacite rock are characterised by an intense fracture pattern. These fractures are likely to be the result of either cooling at relatively shallow depths or tectonic activity.

A small area of granite rock is located towards the centre of Site B. Both the granite and rhyodacite rocks are intersected by dolerite dykes that appear on aerial photography as linear 'scars' on the landscape. It is likely that the majority of these dykes represent tensional fractures and faults (Dames and Moore 1998b). Alluvial deposits including muds, sands, gravels, cobble and boulders occur within the dolerite dykes or channels and takes the form of either uncemented recent alluvium deposits or as older Pleistocene alluvium. The latter occurs within steep linear valleys.

The rock pile features that appear across the site are the weathered remains of the intrusive Gidley Granophyre. The outcrops consist of reddish-brown split-boulder screes largely devoid of vegetation.

The majority of soils at Site B are thin and develop between the outcrops of rhyodacite and occur under boulders. These soils comprise clayey sandy gravels with a thickness that varies across the site of 0–2 m (Dames and Moore 1998b). The soil has developed in-situ as a result of erosion of the underlying rhyodacite. There is a rapid transition between soil to very strong rock and the soil-rock interface is irregular.

Thicker soils are also present which have been subject to calcretisation or the deposition of calcium carbonate within the soil mass and underlying rock fractures (Dames and Moore 1998b). The carbonate can occur as either fined grained constituents of the soil or coarse forms including nodules or lenses up to several centimetres in thickness.

Site A

Site A is located within a granophyre and granite promontory and the geology of this area is typical of the Burrup Peninsula, with granophyre rock piles across the majority of the site (Astron Environmental 2005a).

In the southern portion of the site the north-east banding is interrupted by deep ravines or gullies developed over preferentially weathered dolerite. Alluvial deposits here include mixtures of silt, clay, sand, gravel and calcrete with cobbles and boulders.

Areas of outcrops in the north-east of the site are separated by colluvium (sandy gravels with cobbles and boulders). Red shallow sands occupy the upper and lower hill slopes (Van Vreeswyk et al. 2004). The lower coastal terrain (including the alluvial flat) is expected to comprise colluvium and river bed soils (Van Vreeswyk et al. 2004). These soils exhibit sediment layers of coarse loose sand, clayey sand, silty sand and silty clay. The alluvial fan is a depositional feature and the soil profile is expected to be deeper towards the coastline underlain by highly weathered granophyre. The southern area of Site A is also underlain by dolerite dykes.

The coastal headland at Holden Point contains granite and Quaternary sediments, consisting of both younger (shell rich) and older (silty) Holocene beach and sand dunes (Dames and Moore 1998b). These white to tan sands overlie a harder, variable sequence of sediments which includes calcarenite, coquina, sand, conglomerate and clayey gravel deposits. Landward of the sands are red brown Holocene silty sands that represent an earlier period of coastal dune development. The Holocene sands lie directly above the rhyodacite or granite bedrock.

The sandy beach consists of calcareous deep sands, which are deep white, grey and brown in colour (Van Vreeswyk et al. 2004). Cemented beach conglomerate is exposed at the southern end of this headland.

8.2.3.3 Acid Sulfate Soils

Acid Sulfate Soils (ASS) are soils that contain iron sulfides which, when drained or disturbed, produce sulfuric acid and result in the release of soluble iron, sulfate, aluminium and other toxic metals into the soil and groundwater. These soils commonly have a pH of between four and six. Their distribution is commonly associated with coastal regions and features including freshwater wetlands, tidal flats, floodplains, shallow estuarine marine deposits and saline sulfate rich groundwater. The identification and investigation of ASS (DoE Draft 2006b) details a two-step process of investigation:

- a desktop assessment and preliminary site investigation
- sample selection and laboratory analysis.

A preliminary desktop assessment on the potential for ASS occurrence in the Development area has been conducted in accordance with the principles of Section 3.2 of the 'Draft Identification and Investigation of Acid Sulfate Soils – Acid Sulfate Soils Guideline Series' (DoE Draft 2006b). This comprised a review of generic soil maps, environmental geological maps, topographic maps, aerial photographs and other local investigations or environmental impact assessment reports from the area.

Searches of the DoE ASS risk mapping (WAPC 2006) and Natural Heritage Trust's Australian Natural Resources Atlas (2006) revealed that there are no data sets for Actual Acid Sulfate Soils (AASS) or Potential Acid Sulfate Soil (PASS) mapping covering the Burrup Peninsula and surrounding areas. The ASS Risk Map – Pilbara Coastline presents broad-scale mapping of potential risk areas for the region, including the Burrup Peninsula and is presented in **Figure 8-5**. This data has not been ground-truthed and is not intended to provide site-specific information (DoE 2006b). In the absence of site-specific datasets, the likelihood of ASS being present on the site was therefore assessed using criteria recommended by the 'Draft Identification and Investigation of Acid Sulfate Soils – Acid Sulfate Soils Guideline Series' (DoE 2006b) as described below.

In determining the risk of ASSs, the DoE Draft guideline recommends the use of seven geomorphic or site description criteria. These criteria are detailed in **Table 8-2** for each of the Development components.

Some soils or subsurface substrates may also have acid generating potential and can release a significant amount of acidity and/or iron when disturbed. These potentially acid-generating substrates are described further in **Table 8-3**.

Table 8-2 ASS Risk Assessment for the Pluto Development Area

Criteria		Gas Trunkline Option 1	Site B	Site A
1	Geologically recent (Holocene) areas such as shallow tidal areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes, waterlogged or scalded areas or coastal alluvial valleys	No	No	Yes
2	Marine or estuarine shales and sediments and tidal lakes	No	No	Yes
3	Areas known to contain peat or a build up of organic material	No	No	No
4	Areas where the highest known watertable level is within three (3) metres of the surface	Unlikely[1, 2]	No	No[3]
5	Land with an elevation of less than 5 m AHD	No	No	No[4]
6	Areas where the dominant vegetation is tolerant of salt, acid and/or water logging conditions	Yes	No	Yes
7	Areas where there exists a combination of sulphidic minerals, waterlogged conditions or high watertable, iron minerals, organic matter or deep estuarine sediments below ground surface	No	No	No

1 Note: A groundwater aquifer is present at the existing NWSV Karratha Gas Plant at 5–7 m in depth. The majority of the gas trunkline Option 1 route will be located within the NWSV Karratha Gas Plant boundary.

2 Note: In the absence of hydrological data, it is possible that part of the trunkline route may occur in areas where the water table level is within 3 m of the surface, although groundwater elevation is likely to be tidally dependant.

3 Note: Groundwater boreholes drilled by Dames and Moore (1998a) in the western section of Site A encountered groundwater at 3 m AHD at a location approximately 7 m AHD. Groundwater measurements at a number of boreholes over a period of 3–10 days identified daily fluctuations in groundwater elevation by up to 0.5 m (May/June 1998).

4 Note: Rocky beach areas in Site A are below 5 m AHD.

Table 8-3 Other Potentially Problematic Acid-Generating Substrates

Criteria		Gas Trunkline Option 1	Site B	Site A
1	Recent Sand Units - Pale Grey Sands and Iron Cemented Organic Rich Sands (Coffee Rock)	No	No	No
2	Dredge Spoil	No	No	No

In the absence of ASS risk mapping for the Burrup Peninsula and north-western Australia, the following ASS risk categories have been adopted based on the DoE's risk categorisation for ASS risk mapping for Metropolitan Perth (WAPC 2006):

- high risk of AASS or PASS <3m from surface
- moderate to low risk of AASS or PASS generally occurring at depths >3 m
- low to no risk of AASS and PASS generally occurring at depths of >3 m.

Utilising the above criteria and an assessment of the nature of soils expected at each site, **Table 8-4** describes the ASS risk rating for each locality. Based on this information, the majority of the Development area including areas where significant earthworks will be undertaken are predicted to have low to no risk of ASS conditions. For areas where no groundwater or geotechnical data exists, such as along the gas trunkline Option 1, the potential for ASS to occur is considered a moderate risk. In addition, the southern part of Site A contains a tidally inundated samphire which is not planned for disturbance but is considered to represent an area of high ASS potential.

8.2.3.4 Contaminated Soils

No contamination is known to be present within the Pluto LNG Development area. However, gas trunkline Option 1 will transect through disturbed land at the existing NWSV Karratha Gas Plant, which may contain soils that may have previously been subject to small surface spill events.

8.2.4 Seismicity

The earthquake risk contained within AS1170.4–1993, Minimum Design Loads on Structures—Earthquake Loads, indicates that the risk of seismic activity occurring on the Burrup Peninsula is moderate (Core Consultative Committee on Waste 2006). This suggests that the magnitude of an earthquake event occurring on the Burrup Peninsula is high, although the corresponding probability of the event actually taking place is 1-in-500 years.

Two earthquakes have been experienced in the Dampier area since European settlement, but there have been no large magnitude, localised events. There have also been a few reports of local minor tremors in the vicinity of the Development area.

Figure 8-5 Acid Sulfate Soils Risk Mapping

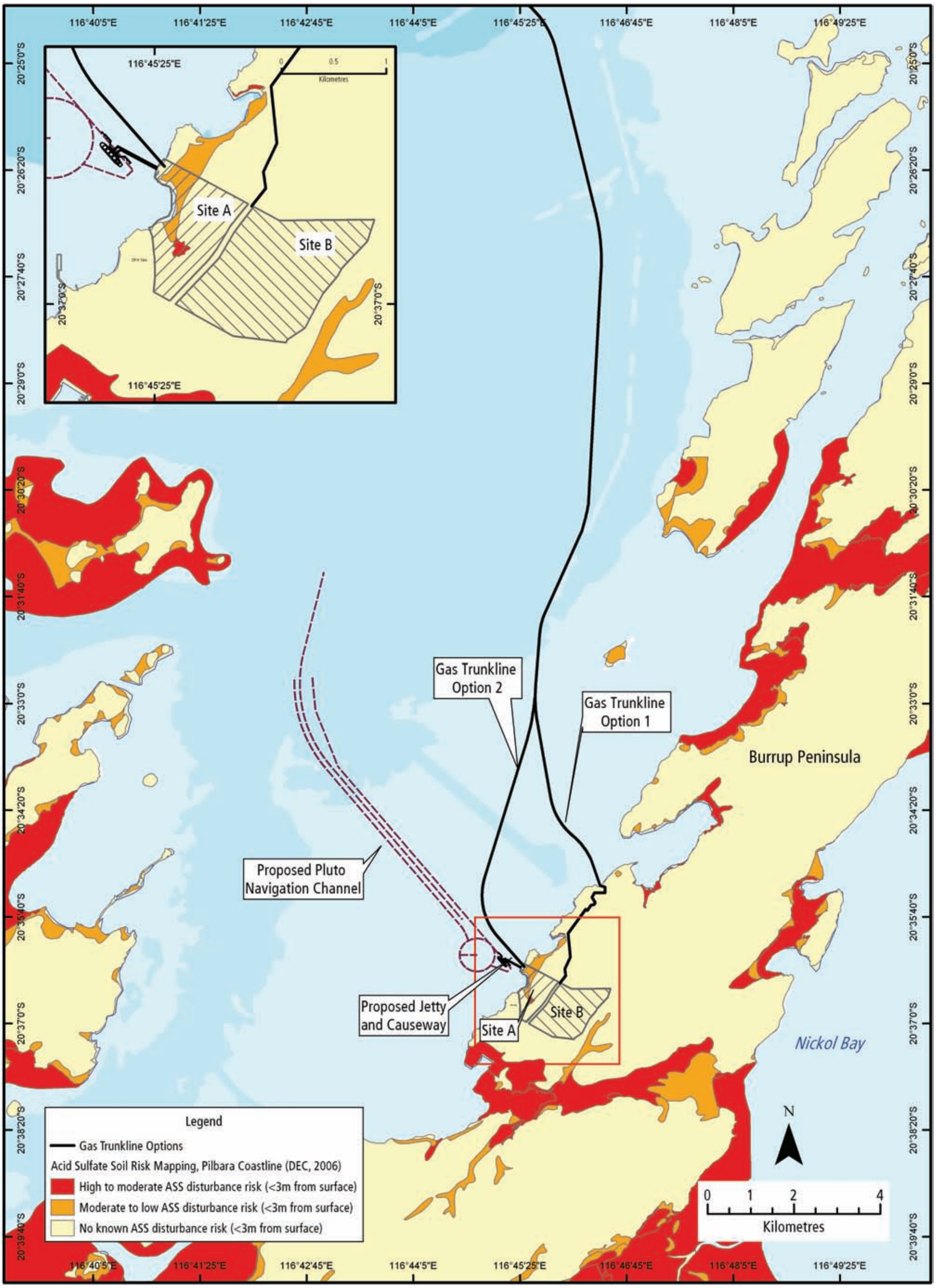


Table 8-4 ASS Risk Ratings for Site B and Site A

Location	
Low Risk Rating	
Site B	Nil
Site A	Nil
Moderate to Low Risk Rating	
Gas trunkline Option 1	No groundwater or geotechnical data available. Area assumed to have moderate risk until further information is available.
Site A - Coastal sands and dunes	Beach and dune sands of Holocene age, located in the wester part of Site A.
High to Moderate Risk Rating	
Site A - Tidal soils which support salt tolerant plant species	An area of samphire (salt tolerant species) in the southern part of Site A is subject to tidal inundation.

8.2.5 Hydrogeology

Regional Setting

The Burrup Peninsula contains groundwater aquifers although none are used for either commercial or domestic abstraction purposes. Groundwater aquifers on the Burrup Peninsula occur as isolated pockets, located in rock fractures, joints, bedding planes and cavities of the rock mass (DEC 2006). Fractured rock aquifers occur as localised systems with regional flow.

The soils and underlying weathered bedrock on the Burrup Peninsula are highly permeable and allow the recharge of groundwater during rainfall events (SKM 2002); however, the presence of granophyre at shallow depths prevents the potential for long-term subsurface water storage.

The granophyre at depth is expected to be a generally tight, solid rock mass with limited open fractures/joints. The orientation, interconnectivity and permeability of these limited open pathways will therefore govern the rate and nature of groundwater movement.

Little groundwater flow is expected to occur from the perched water tables. Instead, this water will be ephemeral and subject to gradual drainage and evaporation (HLA-Envirosciences 1999).

Groundwater Levels

The depth of groundwater aquifers is likely to vary across the Development area, given the contrast in topography between the low-lying coastal sand and dune systems and the elevated Granophyre rock formations.

Groundwater sampling at the existing NWSV Karratha Gas Plant, within which the gas trunkline Option 1 will transect, encountered groundwater within the artificial shallow aquifer from 5.12–7.42 mbgs (URS 2004c). It is noted that the monitoring wells were terminated at the top of the granophyre bedrock which precluded assessment of any deeper aquifer (which may or may not exist).

The depth of groundwater at Site B is unknown, although geotechnical boring undertaken at a number of locations across the site did not encounter any groundwater aquifers within approximately 20 m of the surface (Dames and Moore 1998a).

Geotechnical site investigations undertaken in 1998 indicated that groundwater at Site A, close to Holden Point and in the vicinity of quaternary sediments, occurred at between 0 m and 3 m AHD, and typically at depths deeper than 3 m below the surface (Dames and Moore 1998b). Groundwater elevations increase marginally with distance away from the coast and demonstrated fluctuations of up to 1 m over a 13 day period in May/June 1998 (Dames and Moore 1998b). These fluctuations are likely to be the result of tidal activity. Towards the eastern boundary of Site A, near to the NWSV Haul Road, boreholes drilled as part of the 1998 geotechnical investigations did not encounter any groundwater within 10 m of the surface.

Groundwater Chemistry

The quality of groundwater occurring in the Burrup Peninsula has been previously investigated by HLA-Envirosciences (1999) and indicates that no hydrocarbons or organic compounds occur in groundwater and that levels of metals, sulfates and pH are all within relevant regulatory guidelines—for example, the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC/NHMRC 1992). Groundwater salinity levels are approximately 76 000 µg/cm to 78 000 µg/cm EC units which is higher than the salinity of seawater (up to 50 000 µg/L EC units). Salinity levels in the fractured-rock aquifers are expected to vary seasonally, depending on rainfall recharge events (URS 2006b). During non-rainfall periods the fractured-rock groundwater is expected to become predominantly saline to brackish.

Groundwater Usage

The Department of Water's groundwater bore database does not show any registered boreholes on the Burrup Peninsula. The highly saline nature of the groundwater in the region precludes it from a range of uses including human or livestock consumption and domestic and industrial purposes. The potential for groundwater–surface interaction in the Development area is considered to be minimal.

8.2.6 Hydrology

Regional Setting

The Burrup Peninsula, as with much of the wider Pilbara region, has limited surface freshwater supplies and relies upon inputs during the wet season. As a consequence, freshwater flows in the region are variable and are often experienced as high flow, short period events. The general topography of the Burrup Peninsula is such that surface water flows are channelled off steep slopes into drainage lines and numerous gullies. These high rainfall and short duration events are followed by dry periods that stop stream flow and the recharge of deeper waterholes and gorges.

Gas Trunkline Option 1

Gas trunkline Option 1 crosses few features of hydrological interest. As mentioned previously, large sections of the route transect through the existing NWSV Karratha Gas Plant and previously levelled land. Towards the south of the route, the trunkline parallels the NWSV haul road and crosses over two dolerite drainage channels, prior to entering Site B.

Gas Trunkline Option 2

The gas trunkline Option 2 comes ashore at Holden Point, within Site A, then travels through Site A in an easterly direction before crossing into Site B. As such, hydrology information for the gas trunkline Option 2 corridor is included in Site A and Site B below.

Site B

Storm water drainage at Site B is influenced by rockpile ridges, valleys and gullies (URS 2005b). A rockpile ridgeline parallels the eastern border of the Site B which slopes towards Burrup Road. There are several deep drainage channels that transect the site in a north-west to south-east direction, as discussed previously in **Section 8.2.2**. The upper undulating low slopes in the central portion of the site incorporate numerous very shallow drainage lines that gather water from the upper terrain and feed it to the deeper drainage lines (Astron Environmental 2005b). Towards the south-western corner of the site is a deep gully that drains to the north-west, across the NWSV Haul Road and into the adjacent Site A.

The majority of the proposed Pluto LNG Development within Site B will be located in the centre of the site, thereby minimising disturbance to the deep drainage channels. Development will stretch across the ridgeline extending down the northern and the southern slopes. Several of the shallow drainage lines will be encompassed by the Development and it is expected that the internal drainage will address any site runoff. The deeper gully running through the south-west corner of the site will not be affected by the Development.

The Pluto LNG Development will also occupy the north-eastern area of Site B, again located between two deep rocky gullies that slope in a north-west to south-east direction. Development will stretch across a relatively flat ridgeline that separates the two gullies.

Site A

Most of Site A is located on a localised high point in the landscape and no major external catchments drain through the site. A small catchment that extends along the south-western boundary of Site B runs along a rock lined gully and extends into the southern half of Site A. Surface water occurring in the northern portion of Site A drains to the north-west and into Mermaid Sound. In the southern half of the site, the north-east banding is interrupted by deep ravines or gullies developed over preferentially weathered dolerite and there is also a minor drainage line that flows north-west conveying flows from the Site B catchment. One of these ravines contains an intermittent spring that flows following cyclonic downpour, discharging into a low-lying saline flat.

Development of Site A is limited to a localised high point in the landscape and none of the proposed works traverse any significant gullies or drainage lines.

The predicted 1-in-100 year storm surge is 4.8 m AHD. The majority of Site A has a minimum level of 10 m AHD, which exceeds this level, except for the beach at Holden Point low-lying saline flat which extends below 10 m AHD.

8.3 Ecological Terrestrial Environment

8.3.1 Overview

Various studies have been undertaken to gain a better understanding of the Burrup Peninsula's terrestrial ecological environment. Some of these have been undertaken to gain a regional overview, such as studies by Trudgen (2002) and biological surveys undertaken by CALM (S. van Leeuwen [CALM], pers. comm., 18 November 2005). Other studies are site specific and have been conducted to gain environmental approvals for proposed developments within designated industrial areas on the Burrup Peninsula such as:

- Agrium – Public Environmental Review (URS 2006b)
- Methanol Plant Burrup Peninsula—Public Environmental Review (URS 2003b)
- Methanol Complex Burrup Peninsula—Public Environmental Review (SKM 2002)
- Proposed 2200 tpd Ammonia Plant—Public Environmental Review (SKM 2001)
- Proposed Gas to Synthetic Hydrocarbons Plant—Consultative Environmental Review (HLA Envirosciences 1999)
- Burrup Peninsula World Scale Ammonia Urea Plant—Consultative Environmental Review (Woodward-Clyde 1998).

Site-specific vegetation and flora surveys have been undertaken for the Pluto LNG Development, and are discussed in the following sections.

8.3.2 Vegetation

The Burrup Peninsula occurs within the Fortescue Botanical District of the Pilbara region, as defined by Beard (1975), and the Pilbara biogeographic region in the Interim Biogeographic Regionalisation for Australia (Thackway and Cresswell 1995). It forms part of the broad Abydos Plain physiographic unit, which extends from Cape Preston east to Pardoo Creek, and south to the Chichesters. This unit includes alluvial plains, low stony hills and granite outcrops, and comprises largely granitic soils with alluvial sands on the coastal portion (Beard 1975). The vegetation of the Burrup Peninsula itself was mapped as *Triodia epactia* (referred to as *T. pungens* by Beard) hummock grassland with very few shrubs.

More recently, the DoIR commissioned Trudgen (2002) to conduct a survey of the Burrup Peninsula and part of the Dampier Archipelago. Trudgen's core survey area encompassed the Burrup Peninsula, Dolphin Island, Gidley Island and Angel Island. Trudgen (2002) found the Burrup Peninsula to contain some 200 vegetation associations, many with only a small area of occurrence. This confirms the presence of a rich floristic diversity over a relatively small area. All of the Pluto LNG Development lies within Trudgen's survey area.

Vegetation on the Burrup Peninsula is regarded as generally distinct from mainland vegetation, with high levels of flora endemism and high habitat diversity for plants (CALM 2003). The dominant vegetation type of the Burrup Peninsula is broadly described as mid-dense hummock (*Triodia* spp.) grass with mixed scrub and open low woodland, punctuated by habitat and substrate related minor communities. The result is a complex mosaic of vegetation assemblages (Astron Environmental 2005b).

The onshore development sites lie within Trudgen's (2002) assessment area. Regional vegetation associations for Site B and Site A as mapped by Trudgen (2002) are shown in **Figure 8-6** and **Figure 8-7**. Due to the existing disturbance within gas trunkline Option 1, it was not possible to map regional vegetation extent within the proposed corridor (the entire corridor was classified as 'disturbed' by Trudgen 2002). Gas trunkline Option 2 comes ashore at Holden Point, within Site A, then travels through Site A before crossing into Site B. As such, vegetation information for the gas trunkline Option 2 corridor is included in Site A and Site B.

Due to the large number of vegetation associations described regionally and locally in **Section 8.3.2.1** and **Section 8.3.2.2** (over 190 associations), vegetation codes have been used to describe the various sites. Detailed descriptions of the codes and related vegetation associations are provided in **Appendix K**.

8.3.2.1 Regionally Significant Vegetation Communities

The purpose of the survey undertaken by Trudgen (2002) was to provide information on the conservation value of vegetation and flora in the Burrup Peninsula, parts of the Dampier Archipelago and some areas of the mainland. In his report, Trudgen (2002) assessed the regional significance of the vegetation on the Burrup Peninsula based on the minimum area necessary for protection of an ecosystem, using methodologies outlined by the Australian Heritage Commission.

As part of the assessment of significance, Trudgen (2002) mapped the frequency of vegetation types using a scale of 1 to 100 or more occurrences on the Burrup Peninsula. Vegetation associations are considered by Trudgen (2002) as 'rare', and therefore significant, when the associations are represented by less than 10 populations (frequencies) on the Burrup Peninsula. In addition to this, vegetation is also considered significant when less than 30% of the vegetation association's total extent on the Burrup Peninsula occurs within the Burrup Peninsula Conservation Zone (ENV 2006a). Significance is greater if occurrences of individual vegetation associations are limited to the area zoned for industry (Astron Environmental 2005a). Where an activity in industrial or residential areas causes a disturbance to vegetation associations that are also known to occur in the Conservation Zone, that disturbance is potentially acceptable provided that the vegetation association is well represented in the Burrup Peninsula Conservation Zone, and that disturbance to the vegetation is not excessive.

In order to provide a quantitative assessment of the conservation value of vegetation associations located within the Pluto LNG Development, Trudgen's (2002) mapping was used to identify the following elements for each of the vegetation units found within the development area:

- extent of each vegetation unit on the Burrup Peninsula
- frequency at which the vegetation unit occurs
- extent of the vegetation unit represented in the Burrup Peninsula Conservation Zone
- extent of the vegetation unit in the proposed Pluto LNG Development area
- conservation significance of each vegetation unit.

Figure 8-6 Site B Vegetation Associations According to Trudgen (2002)

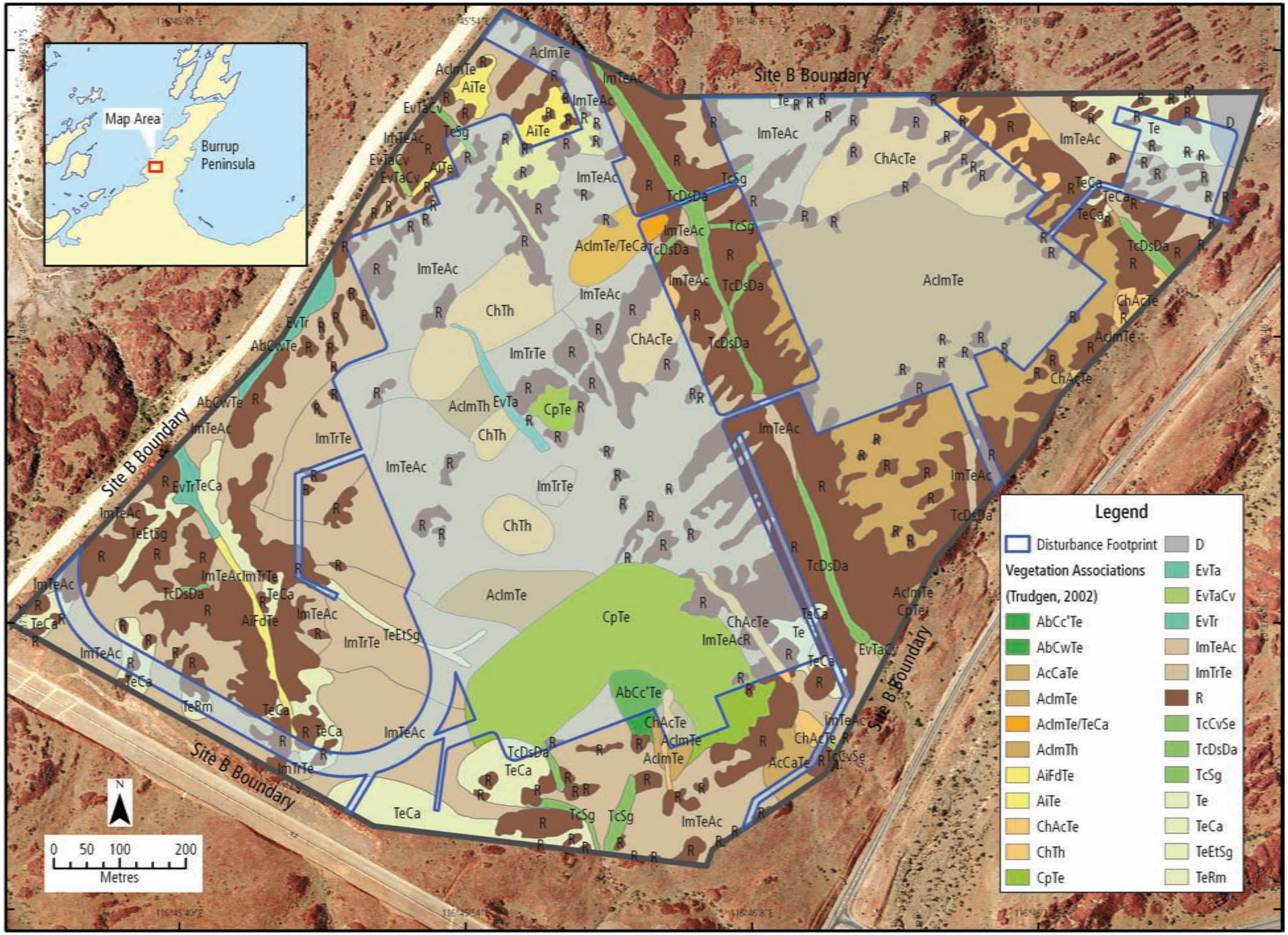
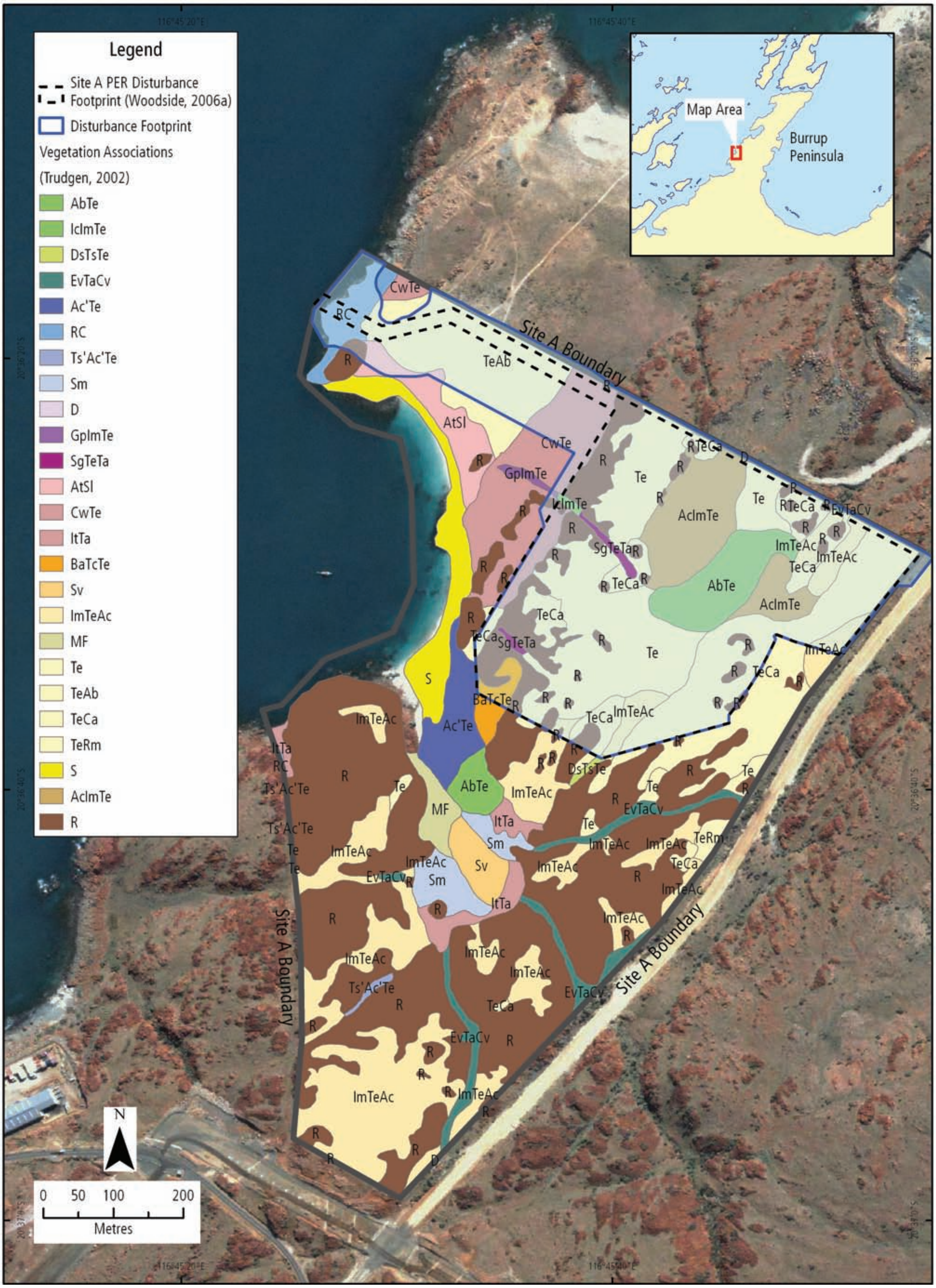


Figure 8-7 Site A Vegetation Associations According to Trudgen (2002)



Using a defined criteria for assessment of significance (associations represented by less than 10 populations across the Burrup Peninsula and/or associations for which the area in the Burrup Peninsula Conservation Zone is less than 30% of the association's total known extent) vegetation associations within the Pluto LNG Development area that were considered to be of high conservation value were identified. These associations are summarised in **Table 8-5** and discussed further on a site-by-site basis below.

Samphire and rock pile vegetation associations were outside the scope of Trudgen's (2002) survey, and as such were not included in that study's assessment of significance. However, it has since been determined that these two associations are significant due to their limited occurrence on the Burrup Peninsula. They have therefore been included in **Table 8-5**.

Gas Trunkline Option 1

The gas trunkline Option 1 corridor occurs within a highly disturbed environment. No vegetation associations identified by Trudgen (2002) are present and as such there is no regional vegetation of conservation significance within the trunkline corridor.

Gas Trunkline Option 2

The gas trunkline Option 2 comes ashore at Holden Point, within Site A. It then travels through Site A in an easterly direction before crossing into Site B. As such, vegetation for the gas trunkline Option 2 corridor is discussed in the following sections on Site A and Site B below.

Site B

Trudgen (2002) recorded 10 vegetation associations considered to be of high conservation value in Site B, these being AbCc'Te, AbCwTe, AcCaTe, AcImTe/TeCa, AiFdTe, R, TcCvSe, TeCa, TeEtSg and TeRm. Most of these vegetation associations will be affected by development within Site B to some degree, with the exception of AbCwTe and TcCvSe which occur outside the disturbance footprint for Site B. It must be noted that a field survey undertaken in 2005 concluded that vegetation associations AbCcTe and AiFdTe no longer occur within the site (Astron Environmental 2005b).

Site A

Vegetation clearing within Site A will occur in two stages. The first stage involves the clearing of 15–20 ha of land for site preparation within the storage facility footprint. Site preparation activities are being formally assessed under a separate environmental approval process (Woodside 2006a). The second stage will involve additional clearing for trunkline and road corridors and some utilities as described in this Draft PER (**Figure 8-7**).

At a regional level, 14 vegetation associations within Site A are considered by Trudgen (2002) to be of high conservation value; Ac'Te, BaTcTe, CwTe, DsTsTe, GpImTe, IcImTe, R, SgTeTa, Sm, Sv, TeAb, TeCa, TeRm and Ts'Ac'Te. In total, 10 of these associations will be disturbed by the two activities within Site A; site preparations works (Woodside 2006a) and construction of the Pluto LNG Development (this Draft PER). The remaining four vegetation associations lie outside the Site A disturbance footprint, as shown in **Table 8-6**.

8.3.2.2 Local Vegetation

In order to supplement the regional vegetation descriptions provided by Trudgen (2002), individual field surveys were undertaken within the Pluto LNG Development area to describe the vegetation and flora on a local scale. Surveys have included:

- Gas trunkline Option 1 – The site was surveyed by ENV (2006b) in June 2006. The results of the survey are presented in this Draft PER.
- Site B South – The site was surveyed by Astron Environmental (2005b) in August 2005, commissioned by URS Australia on behalf of a previous proponent, Agrium Australia Pty Ltd. The results of the survey are presented in this Draft PER.
- Site B North – This site was surveyed by ENV (2006a) in May 2006. The results of the survey are presented in this Draft PER.
- Site A – This site was surveyed by Astron Environmental (2005a) in September 2005 on behalf of Woodside; the results of the survey are presented in this Draft PER.

The field surveys for Site B were undertaken at two different times. The southern portion of the site was surveyed by Astron Environmental (2005b) and the northern portion (Site B North) by ENV (2006a). The two surveys were conducted nine months apart and by different companies, resulting in the use of different nomenclature and mapping units, therefore it was not possible to merge the survey results. The following discussion on local vegetation therefore comprises Site B North and Site B South rather than Site B as a whole.

The vegetation surveys within the Pluto LNG Development were all conducted by foot with a combination of 50 x 50m quadrants and transects (or relevees) (Astron Environmental 2005a, 2005b; ENV 2006a, 2006b).

Rainfall between 2001 and March 2005 on the Burrup Peninsula was below average. However, a significant rainfall event occurred in April 2005 with good follow up rains in May, June and July. This resulted in ideal conditions for good representation of vegetation and the presence of a large range of flora for the Site A and Site B South surveys conducted by Astron Environmental (2005a; 2005b). Significant rainfall during March and April 2006 provided good conditions for the Site B North and the gas trunkline Option 1 surveys (ENV 2006a; 2006b). Ephemeral and annual species were present and many species were in flower during the surveys.

Table 8-5 Significant Regional Vegetation Associations within Site B and Site A (According to Trudgen 2002)

Vegetation Association	Total Area on Burrup Peninsula (ha)	Total Coverage in Site B and Site A (Prior to Clearing)			Total Coverage in Site B and Site A (%)	Total Area In Burrup Peninsula Conservation Zone (%)	Area in Other Areas of the Burrup Peninsula (%)
		Site B (ha)	Site A (ha)	Total (Site B and Site A) (ha)			
AbCc'Te	0.68	0.55	0	0.55	80.9	19.0	0.1
AbCwTe	64.52	0.0043	0	0.0043	0.0	5.1	94.9
AcCaTe	3.48	0.52	0	0.52	14.9	0.0	85.1
AcImTe/TeCa	0.9	0.9	0	0.9	100.0	0.0	0.0
Ac'Te	3.02	0	0.98	0.98	32.5	16.3	51.2
AiFdTe	16.8	0.33	0	0.33	2.0	11.9	86.1
BaTcTe	1.8	0	0.39	0.39	21.7	78.2	0.1
CwTe	13.91	0	3.11	3.11	22.4	0.0	77.6
DsTsTe	1.08	0	0.05	0.05	4.6	94.4	1.0
GpImTe[3]	14.21	0	0.088	0.088	0.6	64.0	35.4
IcImTe	0.23	0	0.044	0.044	19.1	0.0	80.9
R[1]	2068.25	36.01	18.77	54.78	2.6	83.0	14.4
SgTeTa[3]	2.15	0	0.15	0.15	7.0	52.4	40.6
Sm[2]	99.82	0	0.82	0.82	0.8	56.7	42.5
Sv	1.08	0	0.56	0.56	51.9	40.3	7.8
TcCvSe	0.95	0.014	0	0.014	1.5	23.7	74.8
TeAb	85.2	0	3.13	3.13	3.7	16.5	79.8
TeCa	36.09	4.33	6.17	10.5	29.1	4.3	66.6
TeEtSg	1.16	0.58	0	0.58	50.0	0.0	50.0
TeRm	51.74	0.14	0.18	0.32	0.6	20.0	79.4
Ts'Ac'Te	0.36	0	0.081	0.081	22.5	0.0	77.5

Note 1: R (rockpile vegetation) was outside Trudgen's (2002) scope of work, but has since been determined to be of regional significance.

Note 2: Sm (samphire vegetation) was outside Trudgen's (2002) scope of work, but has since been determined to be of regional significance.

Note 3: GpImTe and SgTeTa do not meet the defined criteria for significance (less then 10 occurrences and/or less then 30% in the Burrup Conservation Zone) however they were noted to be of significance in Site A by Astron Environmental (2005a) and have therefore been included.

The condition of vegetation along gas trunkline Option 1 was described by ENV (2006b) as completely degraded. The trunkline traverses previously developed sites and a large portion is located adjacent to existing roads. Some areas along the trunkline corridor have been previously cleared. Piles of rock fill were observed along with man-made drainage lines. A small amount of native vegetation was observed, however, this was not enough to be able to identify clear vegetation associations within the corridor (ENV 2006b).

Gas trunkline Option 2 occurs within Site A and Site B, therefore mapping of vegetation associations within the trunkline corridor has been considered in the separate descriptions of Site A and Site B below.

A summary of the vegetation habitats and number of associations found at a local scale for Site B and Site A is provided in **Table 8-7**. Relevant association descriptions are provided in **Appendix K**.

Local scale vegetation associations for Site B South (Astron Environmental 2005b), Site B North (ENV 2006a) and Site A (Astron Environmental 2005a) are shown in **Figure 8-8** to **Figure 8-10**. Vegetation associations mapped for the Pluto LNG Development have been determined by floristic communities (groups of flora species which comprise the vegetation), vegetation structure (the height of plants, their shape and structure) and environmental variables such as landform, topography, slope and soils.

Table 8-6 Summary of Regional Vegetation Associations of Conservation Significance within Site A

Vegetation Association (Trudgen 2002)	Total Coverage within Site A (ha)	Previous Clearing in Site A by site preparation works (ha) (Woodside 2006a)	Additional Clearing for Pluto LNG Development (ha) (this Draft PER)	Total Clearing within Site A (ha) (Previous Clearing and Additional Clearing)
Ac'Te	0.98	0.007	0	0.007
BaTcTe	0.39	0.205	0	0.205
CwTe	3.11	0.52	0.86	1.38
DsTsTe	0.05	0.0033	0	0.0033
GpImTe#	0.09	0	0.0072	0.0072
IcImTe	0.04	0.039	0.0045	0.044
R	18.77	2.57	0.18	2.75
SgTeTa#	0.15	0.15	0	0.15
Sm	0.82	0	0	0
Sv	0.56	0	0	0
TeAb	3.13	0.61	1.98	2.59
TeCa	6.17	4.08	0.16	4.24
TeRm	0.18	0	0	0
TsAcTe	0.08	0	0	0

Note #: GpImTe and SgTeTa do not meet the defined criteria for significance (less then 10 occurrences and/or less then 30% in the Burrup Conservation Zone) however they were noted to be of significance in Site A by Astron Environmental (2005a) and have therefore been included.

Table 8-7 Summary of Local Vegetation Habitats and Associations within the Pluto LNG Development Area

Site B South (Astron Environmental 2005b)	Site B North (ENV 2006a)	Site A (Astron Environmental 2005a)
Rocky ridges, rockpiles and gully walls 3 vegetation associations	Rockpiles 12 vegetation associations	Rocky ridges, outcrops and gully walls 3 vegetation associations
Drainage Lines and Gullies 9 vegetation associations	Drainage lines 6 vegetation associations	Drainage Lines and Gullies 13 vegetation associations
Upper Undulating Hill Slopes And Plateau 12 vegetation associations	Crest Above Drainage Lines 1 vegetation association	Rocky Hill Slopes and Upper Undulating Slopes 9 vegetation associations
Low rounded hill crests 1 vegetation association	Upland swales 4 vegetation associations	Upper and Lower Valley Systems 3 vegetation associations
Stepped Terraces 1 vegetation association	Upper Stony Plateau 18 vegetation associations	Undulating Coastal Dunes and Flats 2 vegetation associations
	Gentle Slopes Adjacent to Rock Piles 2 vegetation associations	Beach Dune 2 vegetation associations
		Samphire Flat 1 vegetation association

Figure 8-8 Site B South Vegetation Associations According to Astron Environmental (2005b)

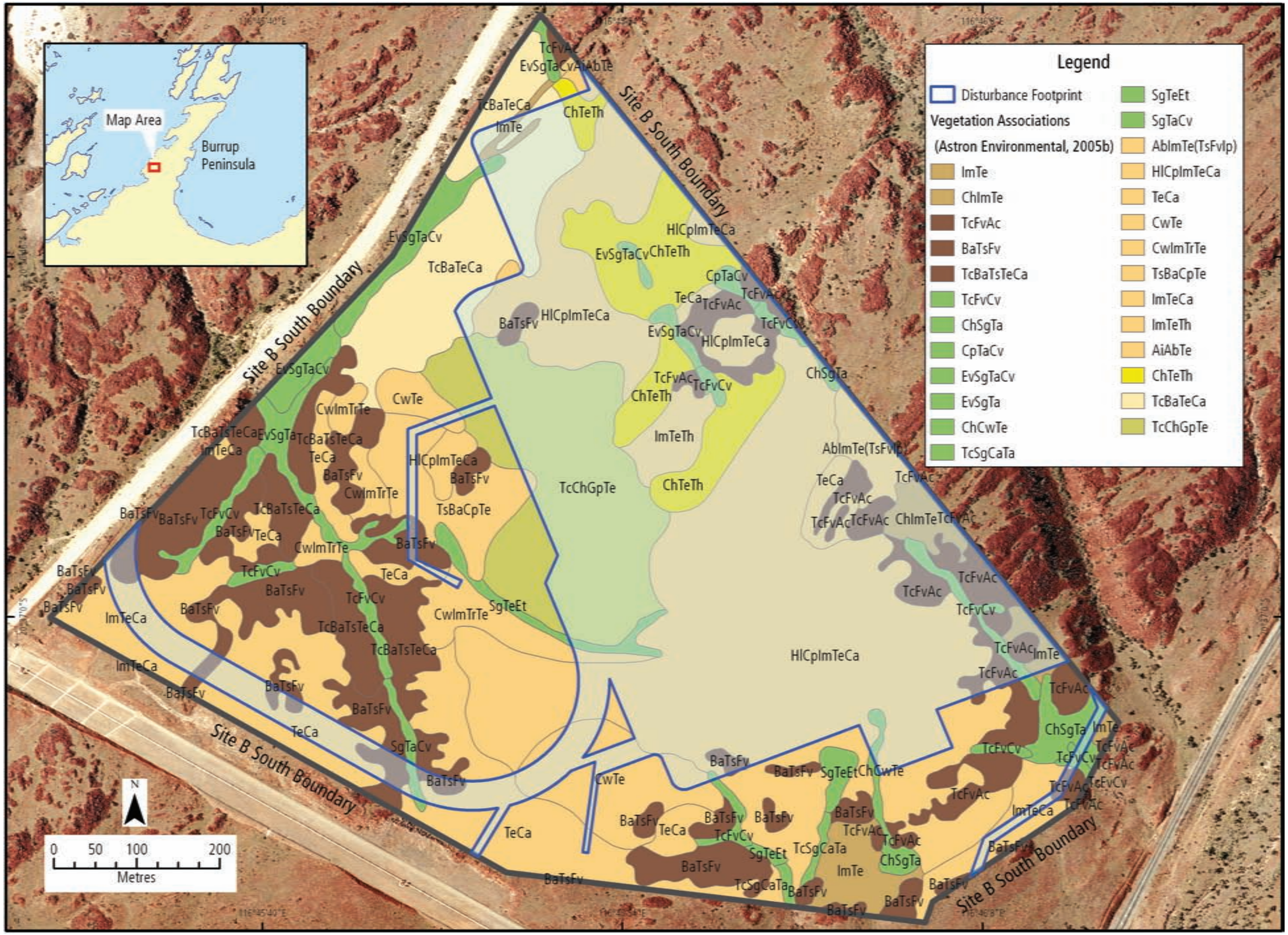


Figure 8-9 Site B North Vegetation Associations According to ENV (2006a)

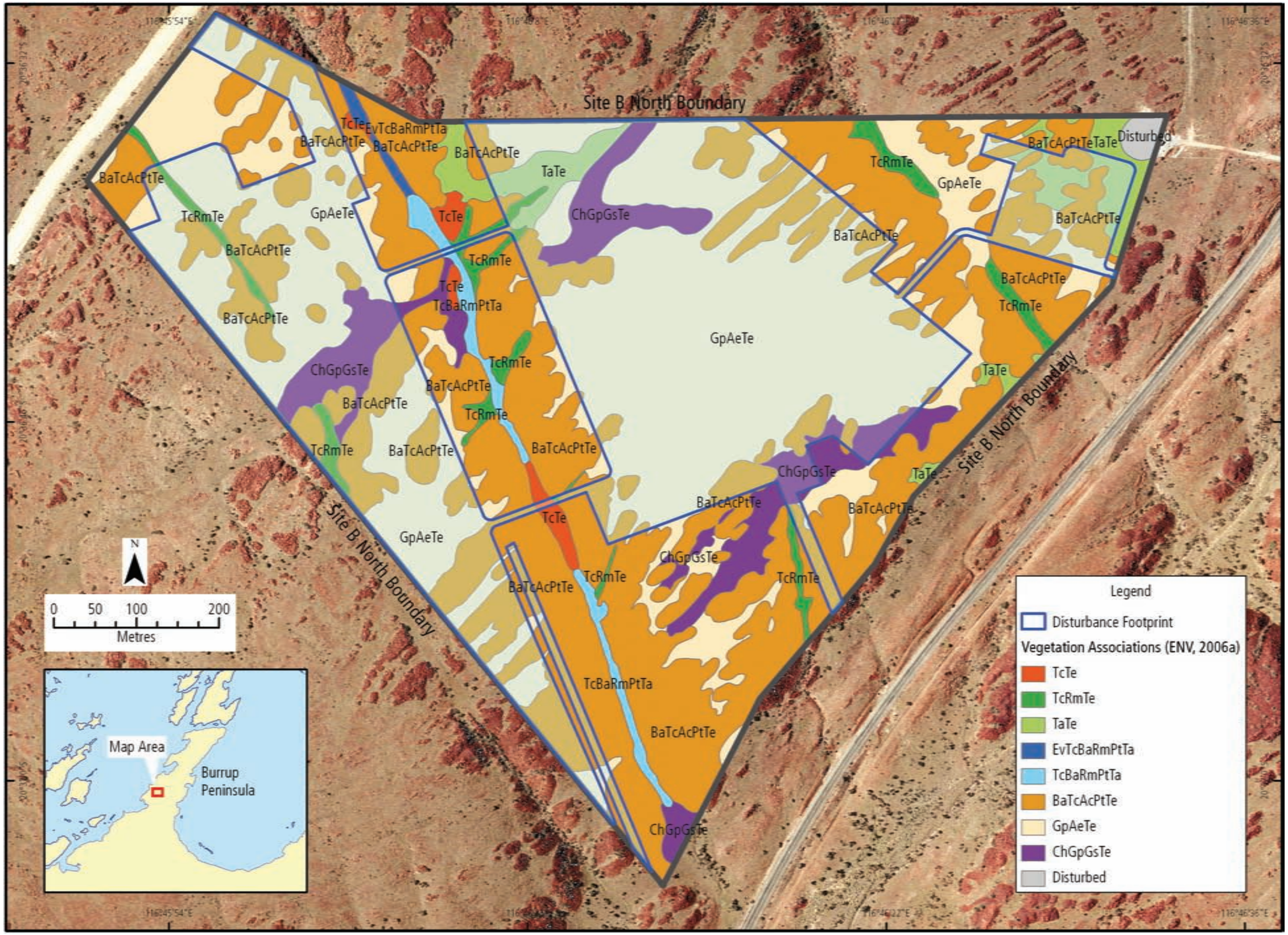
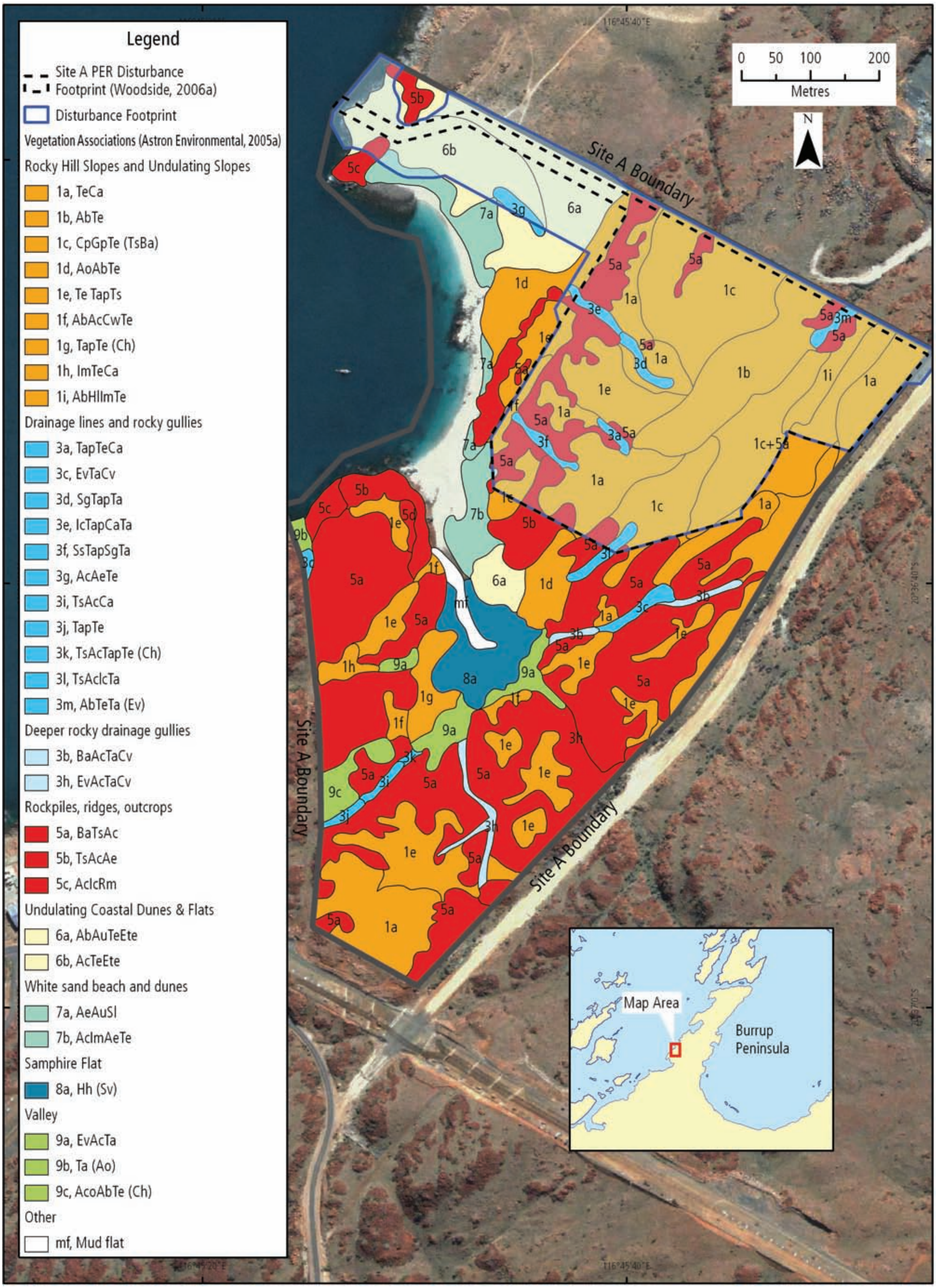


Figure 8-10 Site A Vegetation Associations According to Astron Environmental (2005a)



It must be noted that the vegetation units mapped by ENV (2006a; 2006b) and Astron Environmental (2005a; 2005b) vary from those mapped by Trudgen (2002). There are many reasons for this, including:

- The local-scale surveys of the various sites within the Pluto LNG Development focussed a greater degree of effort over smaller, more discrete areas. The level of resolution of mapping within these specific sites is therefore higher.
- Some vegetation associations that were mapped by Trudgen (2002) were found not to be present based on the ground-truthing undertaken during the site-specific surveys (Astron Environmental 2005a; 2005b).
- Variations in the methodology for vegetation mapping leads to some degree of variation in the vegetation units when different botanists are investigating the same area.
- Seasonal influence (for example, rainfall and humidity) and abiotic influences (for example, fire or disturbance) have a significant impact on the condition or the successional state of the vegetation in any given area.
- Samphire and rock pile vegetation were outside the scope of work for Trudgen (2002) so these were mapped as habitats rather then detailed vegetation associations. However, Astron Environmental (2005a; 2005b) and ENV (2006a; 2006b) assessed these associations in greater detail and identified multiple vegetation associations within the broader categories of samphire and rock pile vegetation.

8.3.2.3 Local Vegetation Communities

As discussed in **Section 8.3.2.2**, local vegetation units mapped during site surveys by Astron Environmental (2005a; 2005b) and ENV (2006a; 2006b) vary to those mapped on a regional scale by Trudgen (2002). At a local scale, the most restricted habitat types on the Burrup Peninsula include samphire and saline tidal flats, coastal sands and dunes, rockpile vegetation and, drainage line vegetation (Astron Environmental 2005a; ENV 2006a).

Where possible, comparisons between vegetation associations at local (within a site) and regional scales have been made. This provides information regarding the potential for vegetation associations recorded within each site to occur elsewhere; that is, if a local-scale vegetation association is comparable to the floristic composition and structure of a regional vegetation association recorded by Trudgen (2002) then it is quite possible that the local vegetation associations also occur outside of the site.

Where local vegetation associations cannot be easily compared to vegetation associations mapped by Trudgen (2002), the extent beyond the site within which it was recorded is unknown and therefore assumed to be potentially restricted.

Gas Trunkline Option 1

Due to prior disturbance along the length on the gas trunkline Option 1 corridor, no potentially locally restricted vegetation associations were identified (ENV 2006b).

Gas Trunkline Option 2

The gas trunkline Option 2 comes ashore at Holden Point, within Site A. It then travels through Site A in an easterly direction before crossing into Site B. As such, local vegetation associations located within the gas trunkline Option 2 corridor are included in the discussion of Site A and Site B in the following section.

Site B South

Astron Environmental (2005b) identified fourteen potentially locally restricted vegetation associations in Site B South. Three of these associations (BaTsFv, TsBaGpTe and TcBaTeCa) are considered to be significant due to the presence of *Terminalia supranitifolia*, a Priority 3 species and a key component of the three vegetation associations (Astron Environmental 2005b). These vegetation associations occur within Trudgen's (2002) rockpile habitat, therefore comparison to regional vegetation associations is not possible. The remaining potentially restricted associations as defined by Astron Environmental (2005b) are drainage line and rocky gully vegetation or vegetation found on upper undulating hillslopes. A comparison of potentially restricted vegetation with regional associations mapped by Trudgen (2002) is provided in **Table 8-8**.

Site B North

Site B North is located on elevated stony plateaus, therefore locally significant habitat types such as samphire, saline flats, coastal sand and dunes are not present within the site. However, rockpile and drainage line habitats were recorded, and these support some potentially restricted vegetation associations (ENV 2006a). Three drainage line vegetation associations and one rockpile vegetation association were identified in Site B North (**Table 8-9**). Two of the drainage lines and the rockpile vegetation will be disturbed by the Pluto LNG Development.

Table 8-8 Potentially Locally Restricted Vegetation Associations within Site B South – Comparison of Astron Environmental (2005b) with Trudgen (2002)

Astron Environmental 2005b[1]	Trudgen 2002
Drainage lines and rocky gullies	
TcFvCv	TcCvSe
ChSgTa	ChAcTe[3]
CpTaCv	ID[4]
EvSgTaCv	EvTaCv[3]
EvSgTa	EvTa[3]
ChCwTe	ID[4]
TcSgCaTa	TcSg[3]
SgTeEt	TeSgEt
SgTaCv	ID[4]
Upper Undulating hillscopes	
ImTeCa	AcCaTe
TeCa	TeCa
TsBaGpTe	R[2]
Rockpiles, ridges and outcrops	
TcFvAc	R[2]
BaTsFv	R[2]
TcBaTeCa	R[2]

Note 1: Associations shown in bold will be affected by clearing within the disturbance footprint.

Note 2: 'R' (rockpile vegetation) was outside Trudgen's (2002) scope of work. It was not surveyed in detail and was not considered in the analysis of significance of vegetation associations by Trudgen (2002).

Note 3: Not considered of conservation significance by Trudgen (2002)

Note 4: ID Insufficient data to make an adequate comparison between vegetation associations recorded by Trudgen (2002) and Astron Environmental (2005b).

Table 8-9 Potentially Locally Restricted Vegetation Associations within Site B North – Comparison of ENV (2006a) with Trudgen (2002)

ENV 2006a[1]	Trudgen 2002
Rockpiles	
BaTcAcPtTe	R[2]
Major Drainage Line	
EvTcBaRmPtTa	ID[3]
TcBaRmPtTa	ID[3]
Minor Drainage Line	
TcRmTe	ID[3]

Note 1: Associations shown in bold will be affected by clearing within the disturbance footprint.

Note 2: R' (rockpile vegetation) was outside Trudgen's (2002) scope of work. It was not surveyed in detail and was not considered in the analysis of significance of vegetation associations by Trudgen (2002).

Note 3: Not considered of conservation significance by Trudgen (2002)

Site A

Within Site A, there are 20 local vegetation associations that have potentially restricted distributions and 10 of these will be affected by the Pluto LNG Development as described in this Draft PER.

Table 8-10 provides a comparison between vegetation associations as classified by Astron Environmental (2005a) and vegetation associations mapped by Trudgen (2002). Most of the potentially restricted vegetation associations described by Astron Environmental (2005a) within Site A are comparable to associations recorded by Trudgen (2002). Those that cannot be easily compared to Trudgen (2002) are discussed further in this section and in **Section 8.3.2.2**.

Also included in **Table 8-10** are potentially restricted vegetation associations that occur within the site preparation disturbance area of Site A (Woodside 2006a). Whilst the site preparation works are outside the scope of this Draft PER, the vegetation associations have been included to demonstrate cumulative clearing requirements within Site A.

Vegetation associations recorded by Astron Environmental (2005a) that are not easily compared to Trudgen (2002) mapping are associations TapTeCa, AcAeTe, TapTe, TsAcTapTe(Ch), AbTeTa(Ev) and BaAcTaCv. These vegetation associations all occur within drainage lines and rocky gullies. Drainage line vegetation is regarded as important for their generally abundant and diverse moisture dependant species that are relatively rare in the Pilbara landscape. The woodlands and shrubland that are supported by the moist conditions provide refuge for fauna (Astron Environmental 2005a). The removal of TapTeCa and AbTeTa(Ev) from Site A as part of the site preparation works was included in the assessment presented in Woodside (2006a).

Table 8-10 Potentially Locally Restricted Vegetation Associations within Site A – Comparison of Astron Environmental (2005b) with Trudgen (2002)

Astron Environmental 2005a Site preparation works for storage facilities (Woodside 2006a)	Astron Environmental 2005a Additional Clearing for Pluto LNG Development Site Works (this Draft PER)	Trudgen 2002
Drainage lines and rocky gullies		
AbTeTa(Ev)	N/A – 100% removed by site preparation works	ID[4]
TapTeCa	N/A – 100% removed by site preparation works	ID[4]
EvTaCv	EvTaCv	EvTaCv[3] and ItTa[3]
SgTapTa and SsTapSgTa	N/A – 100% removed by site preparation works	SgTeTa
IcTapCaTa	N/A – 100% removed by site preparation works	IclmTe
AcAeTe	**AcAeTe**	ID[4]
TsAcCa	TsAcCa	Ts'Ac'Te
TapTe	TapTe	ID[4]
TsAcTapTe(Ch)	TsAcTapTe(Ch)	ID[4]
TsAcIcTa	TsAcIcTa	DsTsTe
BaAcTaCv	BaAcTaCv	ID[4]
EvAcTaCv	EvAcTaCv	EvTaCv[3]
Rockpiles, ridges and outcrops		
BaTsAc, TsAcAe and AcIcRm	**BaTsAc, TsAcAe** and **AcIcRm**	R[2]
Samphire flat		
Hh(Sv)	Hh(Sv)	Sv[3] and Sm[2]
Rocky hillslopes and undulating slopes		
TeTapTs	**TeTapTs**	BaTcTe
AoAbTe	**AoAbTe**	CwTe
White sand beach and dunes		
AcImAeTe	AcImAeTe	Ac'Te

Note 1: Associations shown in bold will be affected by clearing within the disturbance footprint.

Note 2: 'R' (rockpile vegetation) and 'Sm' (samphire vegetation) were outside Trudgen's (2002) scope of work and therefore were not surveyed in detail.

Note 3: Not considered of conservation significance by Trudgen (2002)

Note 4: ID Insufficient data to make an adequate comparison between vegetation associations recorded by Trudgen (2002) and Astron Environmental (2005a).

8.3.3 Flora

Regional Flora

Regional flora and vegetation surveys have been undertaken for the Burrup Peninsula and adjoining areas of the Dampier Archipelago. In total, 392 flowering vascular species and one native fern species have been recorded for the Burrup Peninsula (Trudgen 2002). The most common families recorded were the Poaceae (grasses) with 58 native species, Papilionaceae (pea family) with 47 species, Malvaceae (Mallow family) with 33 species and Amaranthaceae (Amaranth family) with 28 species.

Trudgen (2002) identified a list of 37 taxa of special interest which are neither Declared Rare Flora nor Priority flora but are of conservation interest for a number of reasons. These taxa are not protected by any specific legal framework and are identified as being of conservation significance for reasons including:

- being uncommon or possibly rare, although not officially recognised due to lack of the appropriate research
- being newly discovered, in which case they may be rare or at least poorly collected or known
- the population in the study area may be at the end of the range of species and therefore of particular conservation significance
- the population in the study area may be a significant extension of the known range of the taxa concerned.

These species were grouped by Trudgen (2002) into one of the following nine categories:

1) uncommon or rare, very restricted, newly recognised taxa
2) not common, very restricted, newly recognised taxa
3) apparently rare, fairly geographically restricted, habitat restricted taxa

4) apparently quite uncommon, but widespread taxa

5) locally common, moderately restricted, newly recognised taxa

6) very uncommon, quite restricted, newly recognised taxa

7) not uncommon where occurs, fairly restricted, newly recognised taxa

8) locally very common to abundant, moderately restricted, newly recognised taxa

9) species at or near their southern end of range and not common locally.

Astron Environmental (2005a; 2005b) identified a limitation to flora field surveys due to a lack of available specimens and/or descriptions of the species of conservation significance, as identified by Trudgen (2002), for confirmation of identification. For some species on Trudgen's (2002) list, there are no specimens or detailed descriptions available in either the Western Australian or Pilbara Regional Herbariums, making verification of specimens very difficult.

As discussed in **Section 8.3.2.2**, individual flora and vegetation surveys were conducted for the gas trunkline Option 1, Site B North, Site B South and Site A. The surveys sought to identify the presence of flora of conservation significance. The flora present at each of the sites are discussed below.

Gas Trunkline Option 1

ENV (2006b) recorded 34 flora species during the field survey of gas trunkline Option 1. No Declared Rare Flora as per the *Wildlife Conservation Act 1950* (WA), or endangered or vulnerable species pursuant to s178 of the EPBC Act, were located along the trunkline corridor.

Three species of conservation interest (Trudgen 2002) were identified. *Sida* aff. *fibulifera* (B64- 13B) is considered as an 'uncommon or rare, very restricted, newly recognised taxon' and has only been recorded from six locations previously on the Burrup Peninsula (ENV 2006b). *Corchorus walcottii* is classed as a 'locally very common to abundant, moderately restricted, newly recognised taxon'. Currently there are approximately 174 individual records (with GPS locations) of this taxon on the Burrup Peninsula (ENV 2006b). The third species, *Triodia epactia* (Burrup form) is also considered as a 'locally very common to abundant, moderately restricted, newly recognised taxon'. *Triodia epactia* (Burrup form) appears to be the most dominant hummock grass of the three species that occur on the Burrup Peninsula.

Gas Trunkline Option 2

Flora species located within the gas trunkline Option 2 are included in Site A and Site B below.

Site B South

A total of 106 vascular plants were recorded at Site B South representing 37 families and 74 genera. The Papilionaceae family was best represented with 12 species, followed by the Poaceae family with 11 species. The most represented genera were *Acacia* with six species and *Goodenia* with four species, followed by *Abutilon* and *Triodia* each represented by three species (Astron Environmental 2005b).

No Declared Rare Flora or flora protected by the EPBC Act were found within Site B South during the survey undertaken by Astron Environmental (2005b). One Priority Flora, as listed on the CALM Declared Rare and Priority Flora List (CALM 2005) was located at Site B South; *Terminalia supranitifolia* (Priority 3).

Terminalia supranitifolia was recorded at seven of the 25 vegetation sampling sites. It was found to be most abundant on rocky hillslopes and small rockpiles in the south-western portion of the site, and also along the northern side of the survey area. An additional survey was undertaken in June 2006 and specifically targeted *Terminalia supranitifolia* within Site B South (ENV 2006c). In total 91 individual plants were recorded and these are shown in **Figure 8-11**, along with records of *Terminalia supranitifolia* in Site B North.

In addition to the Priority flora species, 10 flora species recorded within Site B South are considered to have conservation value (Trudgen 2002; Astron Environmental 2005b):

- *Corchorus walcottii*
- *Euphorbia* sp. (aff. *coghlanii*) – not common, very restricted, newly recognised
- *Euphorbia tannensis* subsp. *eremophila* (Burrup form)
- *Paspalidium tabulatum* (Burrup form)
- *Rhynchosia* sp. Burrup (82-1C)
- *Sida* aff. *cardiophylla* (B22-037)
- *Themeda* sp.Burrup (84)
- *Triodia angusta* (Burrup form)
- *Triodia epactia* (Burrup form)
- *Triumfetta appendiculata* (Burrup form).

Dodonea coriacea was not recognised by Trudgen (2002) as having conservation significance; however Astron Environmental (2005b) does consider this species to be locally significant. According to information compiled from all previous records made for the Burrup Peninsula, *Dodonea coriacea* has not been recorded since the Blackwell survey in 1979. This indicates that *Dodonea coriacea* is poorly collected and therefore relatively rarely occurring on the Burrup Peninsula (Astron Environmental 2005b).

Site B North

A survey undertaken by ENV (2006a) at Site B North recorded a total of 112 taxa, representing 41 families. The most common family identified was Papilionaceae, which was represented by 16 species, followed by Poaceae and Mimosaceae with 10 and seven species recorded respectively.

ENV (2006a) did not record any Declared Rare Flora or flora protected by the EPBC Act. The Priority 3 species *Terminalia supranitifolia* was recorded at four sites during the survey. Within these four sites only one or few individuals were recorded. Locations of *Terminalia supranitifolia* within Site B North are presented in combination with *Terminalia supranitifolia* recorded in Site B South in **Figure 8-11**.

Other significant species recorded in Site B North by ENV (2006a) that are not protected under legislation, but that have been identified as being of conservation interest are:

- *Paspalidium tabulatum* (Burrup form)
- *Themeda* sp. Burrup (B84)
- *Fimbristylis* aff. *dichotoma* (M75-4)
- *Triodia angusta* (Burrup form)
- *Triodia epactia* (Burrup form)
- *Rhynchosia* sp. Burrup (82-1C)
- *Corchorus walcottii*
- *Triumfetta appendiculata* (Burrup form).

Site A

A total of 120 vascular plants were recorded at Site A representing 39 families and 83 genera (Astron Environmental 2005a). The Poaceae family was best represented with 13 species, followed by 11 species of the family Papilionaceae and 10 species of the Chenopodiaceae (chenopod) family. Both *Acacia* and *Euphorbia*, with five species each, were the best represented genera followed by *Ptilotus* with four species (Astron Environmental 2005a).

No Declared Rare Flora or flora protected by the EPBC Act were found within Site A during a survey by Astron Environmental (2005a). One Priority 3 species was recorded during the survey, this being *Terminalia supranitifolia*.

Terminalia supranitifolia was recorded at all areas of the site on low rock piles, outcrops, on the edge of rocky drainage gullies and on high rock piles and ridges. The area between the Dampier Supply Base Road and the NWSV Karratha Gas Plant is believed to hold an abundant population (Astron Environmental 2005a). A survey undertaken in June 2006 specifically targeting *Terminalia supranitifolia* recorded 63 individual plants (ENV 2006d). In addition to this, 102 individual plants were recorded during previous investigations within Site A (ENV 2006d). In total, 165 *Terminalia supranitifolia* plants have been recorded in Site A, as shown in **Figure 8-12**.

In addition to the Priority flora species, twelve flora species recorded within Site A are considered to have significant conservation value (Trudgen 2002; Astron Environmental 2005a):

- *Corchorus walcottii*
- *Euphorbia* aff. *drummondii*
- *Euphorbia* sp. (VL1488-09) – not common, very restricted
- *Euphorbia tannensis* subsp. *eremophila* (Burrup form)
- *Paspalidium tabulatum*
- *Rhynchosia* sp. Burrup (82-1C)
- *Sida* aff. *cardiophylla*
- *Themeda* sp. Burrup (84)
- *Triodia angusta* (Burrup form)
- *Triodia epactia* (Burrup form)
- *Triodia wiseana* (Burrup form)
- *Triumfetta appendiculata* (Burrup form).

Figure 8-11 Location of *Terminalia supranitifolia* in Site B (ENV 2006a; 2006c)

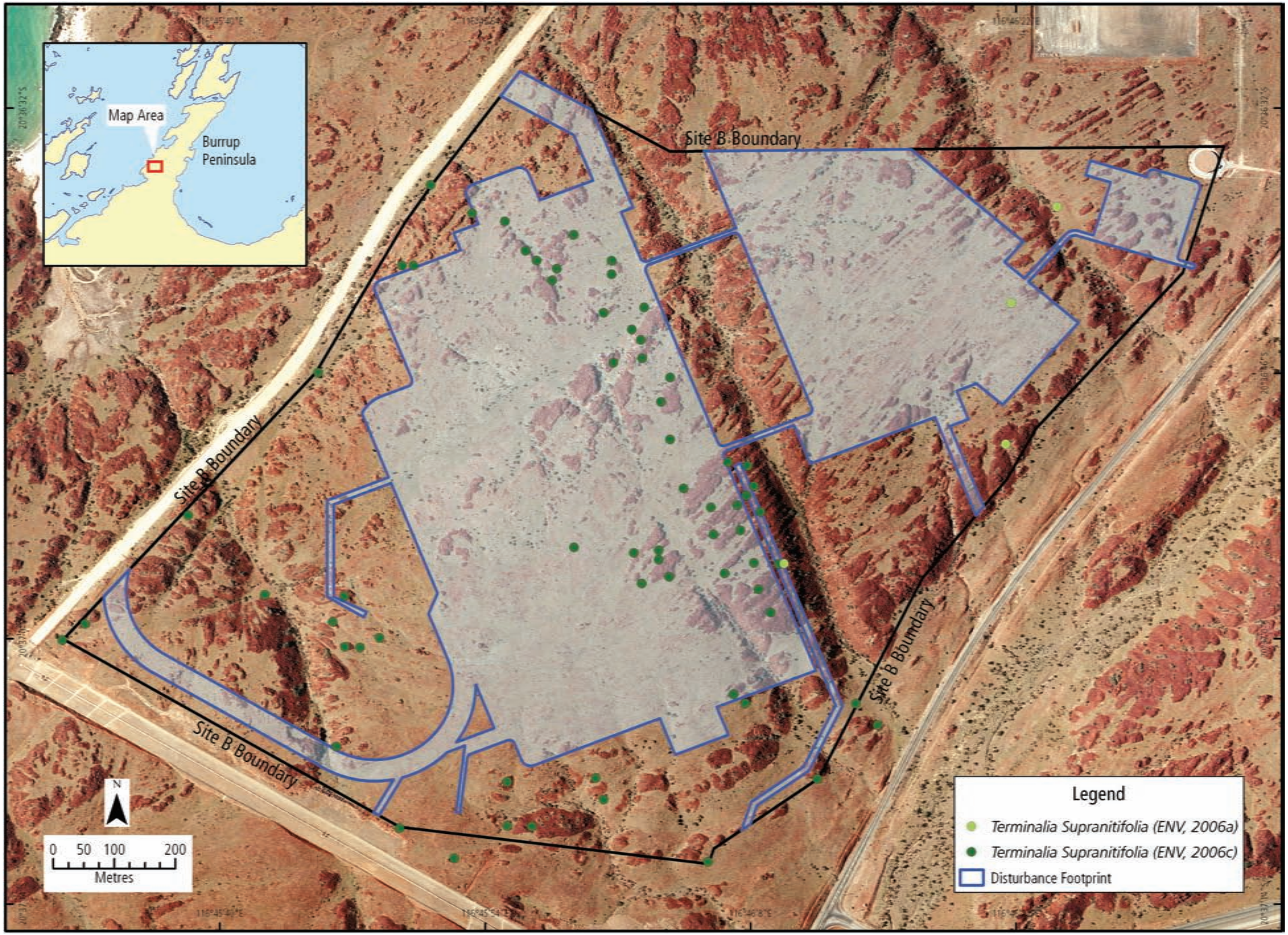
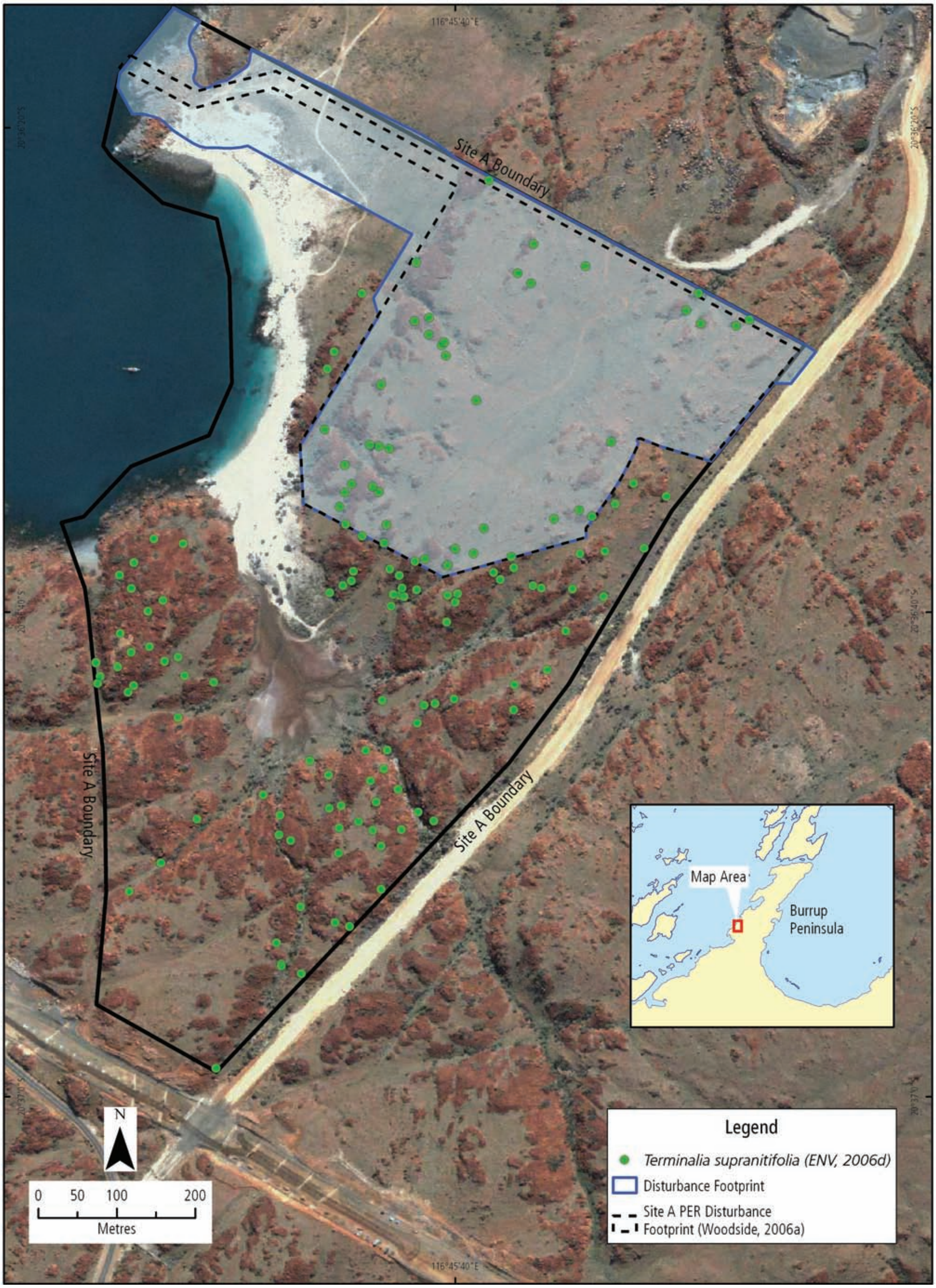


Figure 8-12 Location of *Terminalia supranitifolia* in Site A (ENV 2006d)



8.3.4 Weeds

To date, 13 weed species have been recorded in the Pilbara region including five species that have been rated by DEC as having a high potential impact on the surrounding environment, these being kapok (*Aerva javanica*), birdwood grass (*Cenchrus setigerus*), buffel grass (*Cenchrus ciliaris*), ruby dock (*Rumex vesciarius*) and wild passionfruit (*Passiflora foetida*) (Astron Environmental 2005).

A number of weed species have been recorded throughout the Burrup Peninsula, and also on the surrounding islands of the Dampier Archipelago; the most common weed species on the Burrup Peninsula being buffel grass (*Cenchrus ciliaris*) and kapok (*Aerva javanica*). Buffel grass is a tufted perennial that grows to one metre and is widespread from Shark Bay to the Pilbara (Hussey et al. 1997). Originally from northern Africa and south-west Asia, kapok is a perennial herb that is widespread in Western Australia from Carnarvon to the Kimberley region (Hussey et al. 1997).

No 'Declared Plants', as per the *Agriculture and Related Resources Protection Act 1976* (WA) were found within the entire Pluto LNG Development area; however, seven species of 'Environmental Weed' were recorded (CALM 1999). **Table 8-11** summarises the weed species recorded at the various Development sites.

8.3.5 Fauna

Terrestrial fauna habitats on the Burrup Peninsula are well represented throughout the Pilbara region. There are many fauna habitat types on the Burrup Peninsula, with inland habitats including rocky outcrops, rocky scree slopes, drainage gullies and valleys and coastal habitats such as mangals, beaches, saline flats and rocky coastlines. The fauna of the Burrup Peninsula has been well surveyed and documented, and most vertebrate species are widespread throughout the Pilbara region.

At least 300 vertebrate species have been recorded on the Burrup Peninsula. Approximately 36 mammal species (including four introduced species), 186 bird species, 78 terrestrial reptile species and four amphibian species may inhabit the area; however, none of these are known to be restricted to the Burrup Peninsula alone (Worley Astron 2005).

Mammal species recorded on the Burrup Peninsula include species from families such as Tachyglossidae (echidna), Dasyuridae (quolls, dunnarts), Macropodidae (kangaroos, wallabies), Muridae (mice, rats), Pteropodidae (fruit bats, flying foxes) and Vespertilionidae (vespertilionid bats). Three mammal species are believed to be locally extinct, these being the pale field-rat (*Rattus tunneyi*), western pebble-mound mouse (*Pseudomys chapmani*) and the dingo (*Canis lupus dingo*) (Worley Astron 2005).

The largest group of vertebrate species in the area is birds, with 186 species being recorded including terrestrial species, waders and shorebirds, seabirds and raptors (Worley Astron 2005). The diverse avifauna of the Burrup Peninsula represents, at the family level, approximately 74% and, at the species level, 48% of the total species recorded in the entire Pilbara region. None of the bird species recorded on the Burrup Peninsula are endemic to the area and many are highly mobile. In an arid environment, terrestrial birds often lead a semi-nomadic existence in which they shift in accordance to seasonal or annual conditions to maximise survival.

Table 8-11 Weeds Recorded within the Development Area (Astron Environmental 2005a; Astron Environmental 2005b; ENV 2006a; ENV 2006b)

Scientific Name	Common Name	Environmental Weed Rating (CALM 1999)	Gas Trunkline Option 1	Site B	Site A
Aerva javanica	Kapok	High	Recorded throughout the trunkline corridor	Recorded at one location	Recorded in nine vegetation associations. Abundant on the remnant coastal dunes. Recorded but not abundant in gullies and rocky hill slopes
Cenchrus ciliaris	Buffel grass	High	Not recorded	Recorded 10 times including within drainage lines, on a rockpile and on a hillslope	Recorded in four vegetation associations, these being two gullies, one rockpile and remnant dune, but not abundant at any site
Malvastrum americanum	Spiked malvastrum	Moderate	Recorded at one location	Not recorded	Not recorded
Sonchus oleraceus	Milk thistle	Moderate	Not recorded	Not recorded	Recorded in two vegetation associations, but was not abundant at either site

A large proportion of the fauna on the Burrup Peninsula consists of reptiles. There are many species of Agamidae (dragon lizards), Gekkonidae (geckoes), Scincidae (skinks) and Elapidae (elapid snakes), as well as species belonging to families such as Varanidae (monitor lizards), Pygopodidae (legless lizards) and Boidae (pythons). Some frog species have adapted to the Pilbara climate, including species of Hylidae (tree frogs) such as the burrowing frog (*Cyclorana maini*) and the desert tree frog (*Litoria rubella*), and species of Myobatrachidae, for example, the desert spadefoot (*Notoden nicholisi*).

There is limited information regarding native invertebrate species on the Burrup Peninsula, although information is available regarding some short-range endemic species of terrestrial snail. Short-range endemics are fauna that naturally have a small distribution (short-range) limited to areas less then 10 000 km^2 (Biota Environmental Sciences 2006a; 2006b). Short-range endemic species in Western Australia include millipedes, freshwater and terrestrial snails, trap-door spiders and other species, all of which are considered to have poor methods of dispersal, low levels of fecundity and are generally confined to discontinuous habitats (Biota Environmental Sciences 2006a; 2006b). Very little data is available on short-range endemic species on the Burrup Peninsula, however some surveys have been carried out targeting short-range terrestrial snails (**Section 8.3.6**). Species recorded on the Burrup Peninsula include *Quistrachia legendrei*, *Rhagada* sp., *Pupoides* sp.? *Pupoides beltianus*, *Pupoides contraries*, *Gastrocopta pilbarana*, *Stenopylis coarctata* and *Amerianna* sp. (Slack-Smith 2005).

Four introduced mammal species occur on the Burrup Peninsula: the red fox (*Vulpes vulpes*), the cat (*Felis catus*), the black rat (*Rattus rattus*) and the house mouse (*Mus musculus*). The black rat and house mouse are believed to occur in residential and industrial areas, with the house mouse also being recorded in supra-tidal flats, coastal sands and stony high colluvial areas (Worley Astron 2005). The fox and cat are believed to have wider distributions. Several introduced invertebrate species occur on the Burrup Peninsula, including cockroaches (Order Blatodea), crickets (Order Orthoptera) and honey bees (*Apis mellifera*) (Worley Astron 2005).

Various fauna studies have been undertaken for the Pluto LNG Development:

- A desktop fauna study was undertaken for the proposed development sites (Worley Astron 2005), as numerous field surveys have been undertaken on the Burrup Peninsula and fauna are considered to be well documented. The desktop fauna studies included the review of relevant literature and previous trapping efforts, including recent surveys conducted by CALM and the Western Australian Museum (Worley Astron 2005).
- A land snail survey for Site A was undertaken by the Western Australian Museum in 2005. The results are summarised in the following sections. A follow-up wet season survey that included aquatic snails has since been undertaken by Biota for Site B, Site A and other areas of the Burrup Peninsula.
- A sea turtle survey of Holden Point beach was undertaken to assess the nesting activity on the beach at Site A (Pendoley 2006).

Gas Trunkline Option 1

The majority of the gas trunkline Option 1 corridor is completed degraded (ENV 2006b) therefore a fauna field study was not undertaken for this trunkline route.

Gas Trunkline Option 2

The gas trunkline Option 2 corridor was included in the desktop fauna studies and field surveys undertaken in Site A and Site B below.

Site B

A desktop fauna study was undertaken for Site B as there is a significant amount of information directly available from previous field studies. Field surveys focussing on aquatic and terrestrial snail species were undertaken at Site B, Site A and other areas of the Burrup Peninsula by Biota in May 2006 (Biota Environmental Sciences 2006a; 2006b). The results are discussed in **Section 8.3.6**. A fauna habitat map for Site B, based on landforms and vegetation mapping, is presented in **Figure 8-13**.

Site A

A general fauna survey was not undertaken at Site A due to the wealth of information directly available for the Burrup Peninsula. However, a field survey focussing on terrestrial snail species was conducted at Site A by the Western Australian Museum in October 2005 (Slack-Smith 2005). Further surveys were conducted by Biota in May 2006 (Biota Environmental Sciences 2006a; 2006b). The results of these are discussed in **Section 8.3.6**. A fauna habitat map of Site A is given in **Figure 8-14**.

Figure 8-13 Site B Fauna Habitat Map

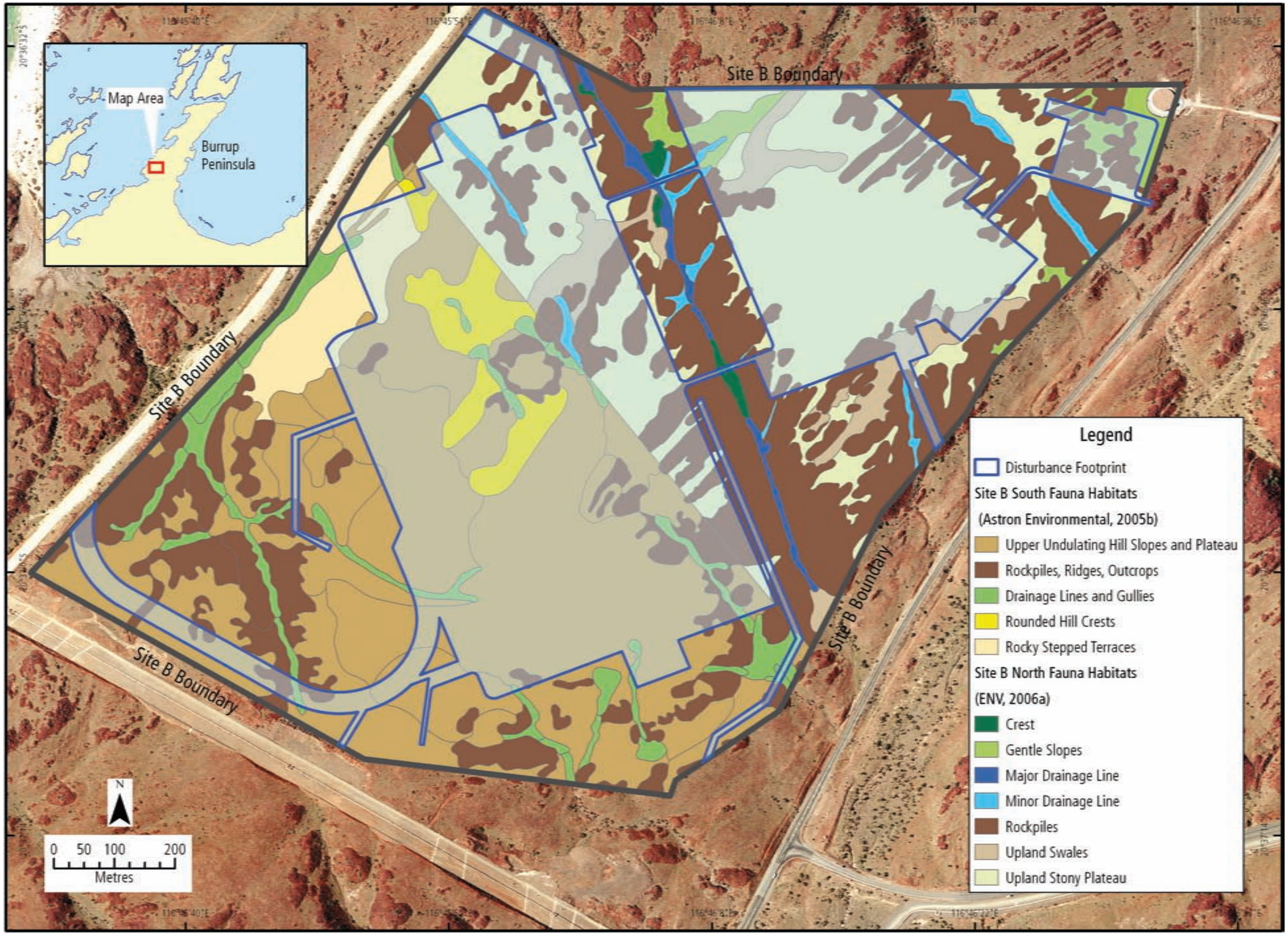
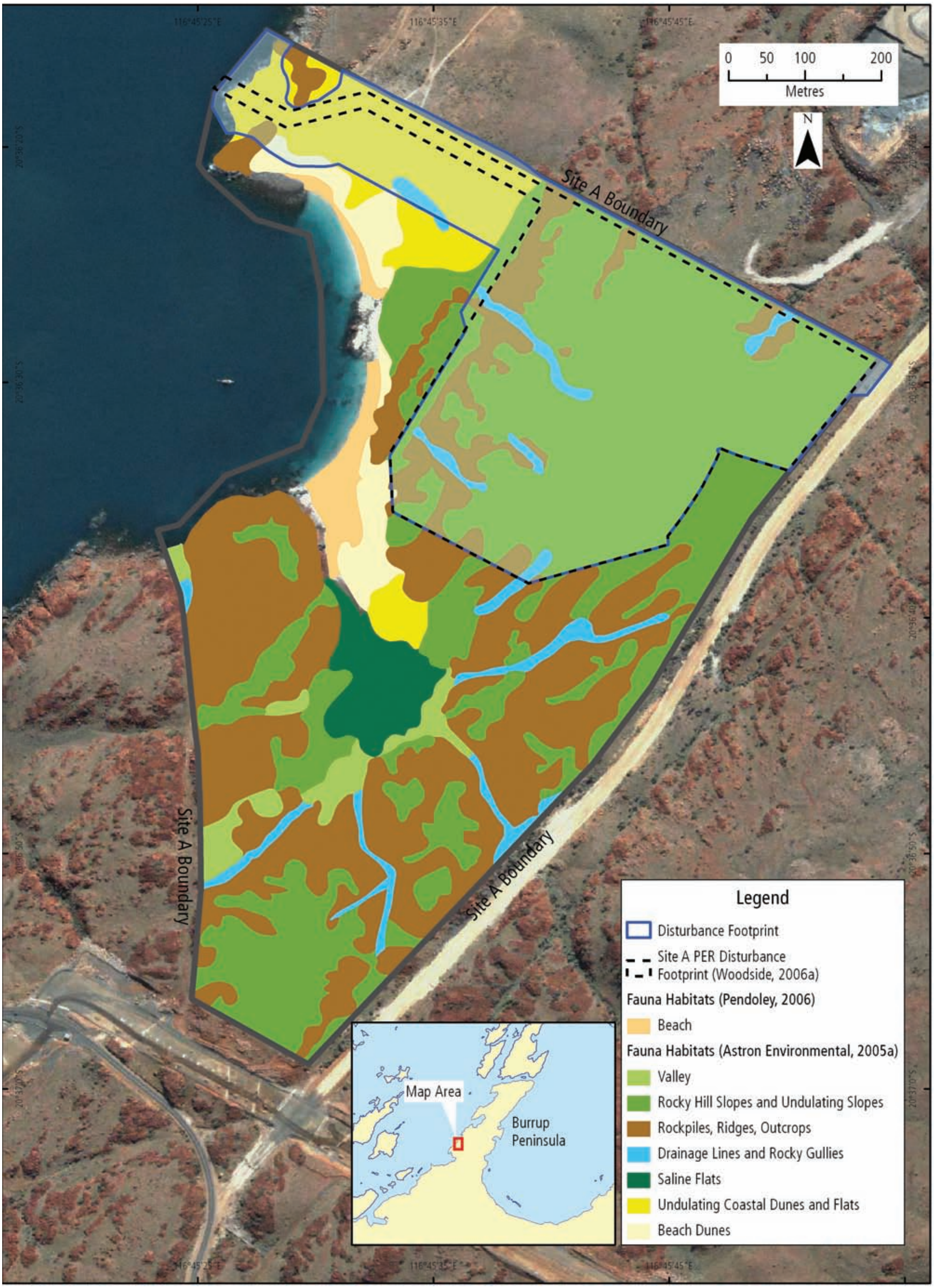


Figure 8-14 Site A Fauna Habitats



8.3.6 Terrestrial Fauna of Conservation Significance

Commonwealth Protected Fauna

A search of the DEH protected matters search tool (DEH 2005a) indicated that three terrestrial fauna species, which are listed as threatened species under the EPBC Act, may occur within or migrate through the Pluto LNG Development area (**Table 8-12**).

The northern quoll (*Dasyurus hallucatus*) is a top order predator whose survival is dependent upon a diverse prey base (Worley Astron 2005). As such, the species is expected to have a large home range in arid environments, and its survival is likely to be adversely affected by loss of drought refuge habitat and its prey. The species was not captured in a recent DEC survey on the Burrup Peninsula; however, it was recorded on the Burrup Peninsula in 1993 by Dr Harry Butler, and is known to occur on Dolphin Island just to the north (I Asmussen [Worley Astron], pers. comm., 5 October 2005).

The Pilbara or orange leaf-nosed bat (*Rhinonicteris aurantius*) has been recorded in the Pilbara and Gascoyne regions of Western Australia, with five breeding sites located in abandoned mines in the east Pilbara and two natural roost sites in the Gascoyne (DEH 2005b). There are two forms of the orange leaf-nosed bat, the Pilbara and Kimberley forms. The two vary slightly in terms of echolocation call and wing morphology, which may reflect the need for the Pilbara form to feed efficiently in the arid environment of the region (Environment Australia 1999). No comprehensive surveys of the bat species have been conducted to date, and although the species is not thought to occur on the Burrup Peninsula, it is highly mobile and roosting sites are sensitive to disturbance (Worley Astron 2005). The orange leaf-nosed bat is considered unlikely to occur in the Pluto LNG Development area as there are no known caves within the gas trunkline options, Site B or Site A.

The Pilbara olive python (*Liasis olivaceus barroni*) is also a top order predator and, like the northern quoll, is believed to have an extensive home range. The python favours deep rock fissures which are common throughout the Burrup Peninsula, and typically occupies a substantial home range in the order of 50 ha to 100 ha (Worley Astron 2005). The species is often found in close proximity to pools of water (Worley Astron 2005). Population density may be related to prey distribution. Surveys completed by the Nickol Bay Naturalists Club indicate that in nearby areas, such as Hearson Cove, the density of the python may be as high as 30 individuals per hectare (S. Van Leeuwin [CALM], pers. comm., 18 November 2005). The Pilbara olive python is expected to utilise the majority of Site B and Site A, including habitats such as rocky hill slopes, drainage lines and gullies, rockpiles, ridges, outcrops and stony plateaus (**Figure 8-13** and **Figure 8-14**). Due to the mobility, extensive home range and natural occurrence of several individuals in overlapping areas, relocation of the Pilbara olive python from existing industrial areas is common practice for operations on the Burrup Peninsula.

State Protected Fauna

The Wildlife Conservation Act 1950 (WA) provides for the protection of native fauna, with species considered as needing special protection being listed under one of four categories in the Wildlife Conservation (Specially Protected Fauna) Notice, these being:

- Schedule 1 – fauna that are rare or likely to become extinct.
- Schedule 2 – fauna presumed to be extinct.
- Schedule 3 – birds that are subject to the JAMBA, which relates to the protection of migratory birds and birds in danger of extinction.
- Schedule 4 – other specially protected fauna.

Species protected under the *Wildlife Conservation Act 1950* (WA) that have the potential to occur within the terrestrial Development area include:

- the northern quoll (*Dasyurus hallucatus*) – Schedule 1
- the Pilbara leaf-nosed bat (*Rhinonicteris aurantius*) – Schedule 1
- the Pilbara olive python (*Liasis olivaceus barroni*) – Schedule 1
- the peregrine falcon (*Falco peregrinus*) – Schedule 4.

The northern quoll (*Dasyurus hallucatus*), Pilbara leaf-nosed bat (*Rhinonicteris aurantius*), and Pilbara olive python (*Liasis olivaceus barroni*) are discussed above under 'Commonwealth Protected Fauna'.

Table 8-12 Terrestrial Species of Conservation Significance (EPBC Act)

Scientific Name	Common Name	Class	Status	Type of Presence
Dasyurus hallucatus	Northern Quoll	Mammal	Endangered	Species or species habitat may occur within area
Rhinonicteris aurantius (Pilbara form)	Pilbara Leaf-nosed Bat	Mammal	Vulnerable	Not recorded Species or species habitat likely to occur within area
Liasis olivaceus barroni	Olive Python (Pilbara subspecies)	Reptile	Vulnerable	Species or species habitat may occur within area

The peregrine falcon (*Falco peregrinus*) is found worldwide, including all in parts of Australia, and is a highly mobile species that inhabits a variety of environments including woodlands, grasslands, coastal cliffs and some desert regions (DEH 2005a). However, notwithstanding its wide distribution, various factors lead to the peregrine falcon being vulnerable to impacts, such as its low reproductive rate, low population density and the fact that the species is a top predator whose distribution is limited by its prey. Within the Pluto LNG Development, it is possible that the peregrine falcon uses habitats for hunting; however it is a wide-ranging predator and would not be specifically dependent on habitats disturbed by the proposed Pluto LNG Development. The peregrine falcon uses cliffs or woodlands for nesting (Garnett and Crowley 2000), therefore it is unlikely that breeding occurs in the Pluto LNG Development area.

Other significant species, according to DEC, that have previously been recorded or may occur on the Burrup Peninsula, and therefore have the potential to occur within the Pluto LNG Development area, include:

- little northwestern mastiff bat (*Mormopterus loriae cobourgensis*) – Priority 1
- skink species (*Lerista planiventralis maryani*) – Priority 1
- skink species (*Lerista quadrivincula*) – Priority 1
- Australian bustard (*Ardeotis australis*) – Priority 4
- bush stone-curlew (*Burhinus grallarius*) – Priority 4
- grey falcon (*Falco hypoleucos*) – Priority 4
- ghost bat (*Macroderma gigas*) – Priority 4
- skink species (*Notoscincus butleri*) – Priority 4
- eastern curlew (*Numenius madagascariensis*) – Priority 4
- western pebble-mound mouse (*Pseudomys chapmani*) – Priority 4
- water rat (*Hydromys chrysogaster*) – Priority 4.

Priority 1 species are known from a few specimens or have been recorded from a few localities on land that is not managed for conservation, for example, agricultural or pastoral lands, urban areas, active mineral leases. Species in this category require further surveys and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority 4 species are adequately surveyed or known and are considered not currently threatened or in need of special protection, but may need special protection if current circumstances change in the future. Priority 4 species are usually represented on conservation lands.

The Priority fauna species have been recorded elsewhere on the Burrup Peninsula or in the Pilbara region, and therefore most have the potential to occur in the Pluto LNG Development area with the exception of the western pebble-mound mouse (*Pseudomys chapmani*) which has not been recently recorded on the Burrup Peninsula or during specific field surveys of the Development area.

The bush stone-curlew (*Burhinus grallarius*) is known to occupy a variety of habitats throughout Australia including open forest, open woodlands, grassy woodlands and scrub. In southern Australia the species is associated with habitats that provide litter and fallen timber; however, in northern Australia, bush stone-curlews also inhabit areas where the ground cover is more open (DEH 2000). It is possible that the bush stone-curlew utilises open shrublands and woodlands within the Pluto LNG Development such as those found on rocky slopes, drainage lines and gullies, valleys, rockpiles and outcrops (**Figure 8-13** and **Figure 8-14**). Being a mobile species, it is also possible that the bush stone curlew moves through other habitats in the Pluto LNG Development including coastal dunes and saline flats.

The little north-western mastiff bat (*Mormopterus loriae cobourgensis*) a Priority 1 species, has been recorded on the Burrup Peninsula (Worley Astron 2005). This species is generally associated with mangroves. As presented in **Figure 8-13** and **Figure 8-14**, there are no mangrove stands within Site B or Site A, however being a highly mobile species that chases insects for food, the little north-western mastiff bat may travel through the Pluto LNG Development.

The ghost bat (*Macroderma gigas*) is predicted to occur on the Burrup Peninsula, and therefore has the potential to occur within the Pluto LNG Development (Worley Astron 2005). The rugged topography of the Burrup Peninsula and the likely occurrence of caves and underground water, means that roost caves may exist. However, there are no known caves within the Pluto LNG Development, so ghost bat use of the habitats within the Pluto LNG Development area is expected to entail foraging only.

Three skink species, *Lerista planiventralis maryani*, *Lerista quadrivincula* and *Notoscincus butleri*, have been recorded in the Pilbara region and are considered to have the potential to occur within the Burrup Peninsula. *Lerista planiventralis maryani* and *Lerista quadrivincula* forage in litter and detritus in hummock grassland, open heath, open scrub and tall shrubland, and have been recorded as occurring within 150 km of the Burrup Peninsula.

The grey falcon (*Falco hypoleucos*) usually occupies shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it is occasionally found near wetlands or in coastal open woodlands. Nests are usually made in the old nests of other birds in tall eucalypts that grow near water. While the grey falcon is associated with drainage lines and watercourses, it also hunts in tussock grassland and open woodland (Garnett and Crowley 2000). It is possible that the grey falcon uses the habitats within the Pluto LNG Development for hunting.

The Australian bustard (*Ardeotis australis*) is a ground-dwelling bird that occupies open habitats where canopy cover is less then 10% such as tussock grasslands, hummock grasslands, low shrublands and grassy woodlands (Pizzey 1991). The species is highly nomadic and appears to move in response to variables such as rainfall, available food and recently burnt country. It is possible that the Australian bustard will utilise habitats within the Pluto LNG Development that support hummock grasslands, open shrubland and low open woodland such as rocky hills slopes and undulating slopes, some drainage lines and gullies, valleys, rockpiles and outcrops, undulating coastal dunes and saline flats (**Figure 8-13** and **Figure 8-14**).

The eastern curlew (*Numenius madagascariensis*) is a migrant shorebird that breeds in eastern Russia and has been recorded as a non-breeding visitor to numerous Asian and Pacific countries. In Australia, the largest numbers of eastern curlew occur on the coastal mudflats of eastern and north-western Australia (Watkins 1993). It is expected that the eastern curlew utilises the 'beach' habitat and 'saline flat' habitat within Site A as feeding habitat during the non-breeding season (approximately August to April) (**Figure 8-14**).

The water rat relies on permanent water (fresh, brackish or marine) and therefore occurs in mainly coastal areas, near inland surface water or in wetland habitats. The status of the water rat (*Hydromys chrysogaster*) is unclear as it has not been recorded recently and may have declined locally (Worley Astron 2005), therefore it is considered unlikely that the water rat occurs in Site A despite the presence of saline flat and beach habitat.

Short Range Endemics – Aquatic and Terrestrial Snails

Surveys for land and aquatic snails have been undertaken at Site B and Site A for the Pluto LNG Development (Slack-Smith 2005; Biota Environmental Sciences 2006a; 2006b). The survey locations are presented in **Figure 8-15**.

A survey of land snails was undertaken by the WA Museum at Site A and nearby areas in October 2005 (Slack-Smith 2005). The survey found land snail shells belonging to a total of seven species: *Quistrachia legendrei*, *Rhagada* sp., *Pupoides* sp.? *Pupoides beltianus*, *Pupoides contraries*, *Gastrocopta pilbarana*, *Stenopylis coarctata* and *Amerianna* sp. (Slack-Smith 2005). These species were located within the Site A disturbance area, as well as many other locations within Site A and the adjacent land west of Site A. Most of the species found have a wide distribution, having been recorded in other areas of the Burrup Peninsula and Dampier Archipelago, as well as in other areas of the North West Cape. Some species, such as *Pupoides contrarius* and *Gastrocopta pilbarana*, have been recorded as far south as Shark Bay, Western Australia (Slack-Smith 2005).

Specimens of the camaenid genus *Rhagada* were found at most survey sites within Site A, including areas within and outside the disturbance area, as well as land to the west of Site A. Some specimens found within Site A showed some differences in shell size and shape and varied from other known *Rhagada* species (Slack-Smith 2005). No patterns relating to area within the study sites or habitat types was evident to explain the morphological variations. It was considered that these specimens were one species, *Rhagada* sp "12" however the significance of the morphological variations could not be determined without further information. **Table 8-13** summarises the number of specimens per species recorded by the WA Museum.

In 2006, Biota collected snail specimens at Site A, Site B and industrial Site E (on the eastern side of the Burrup Peninsula, near Hearson Cove) to gather more information about the *Rhagada* species collected at Site A by the WA Museum in 2005. Genetic analysis using mitochondrial DNA was undertaken to attempt to determine whether the *Rhagada* snails found by the WA Museum at Site A were the same or different species (Biota Environmental Sciences 2006a; 2006b). The snail survey results are summarised in **Table 8-14** and demonstrates that the snails found within Site A and Site B were also found elsewhere on the Burrup Peninsula. A freshwater snail belonging to the genus *Isidorella* was recorded at Site B. No aquatic snails were found at Site A, despite there being a number of small standing pools at water within the site during the survey (Biota Environmental Sciences 2006a).

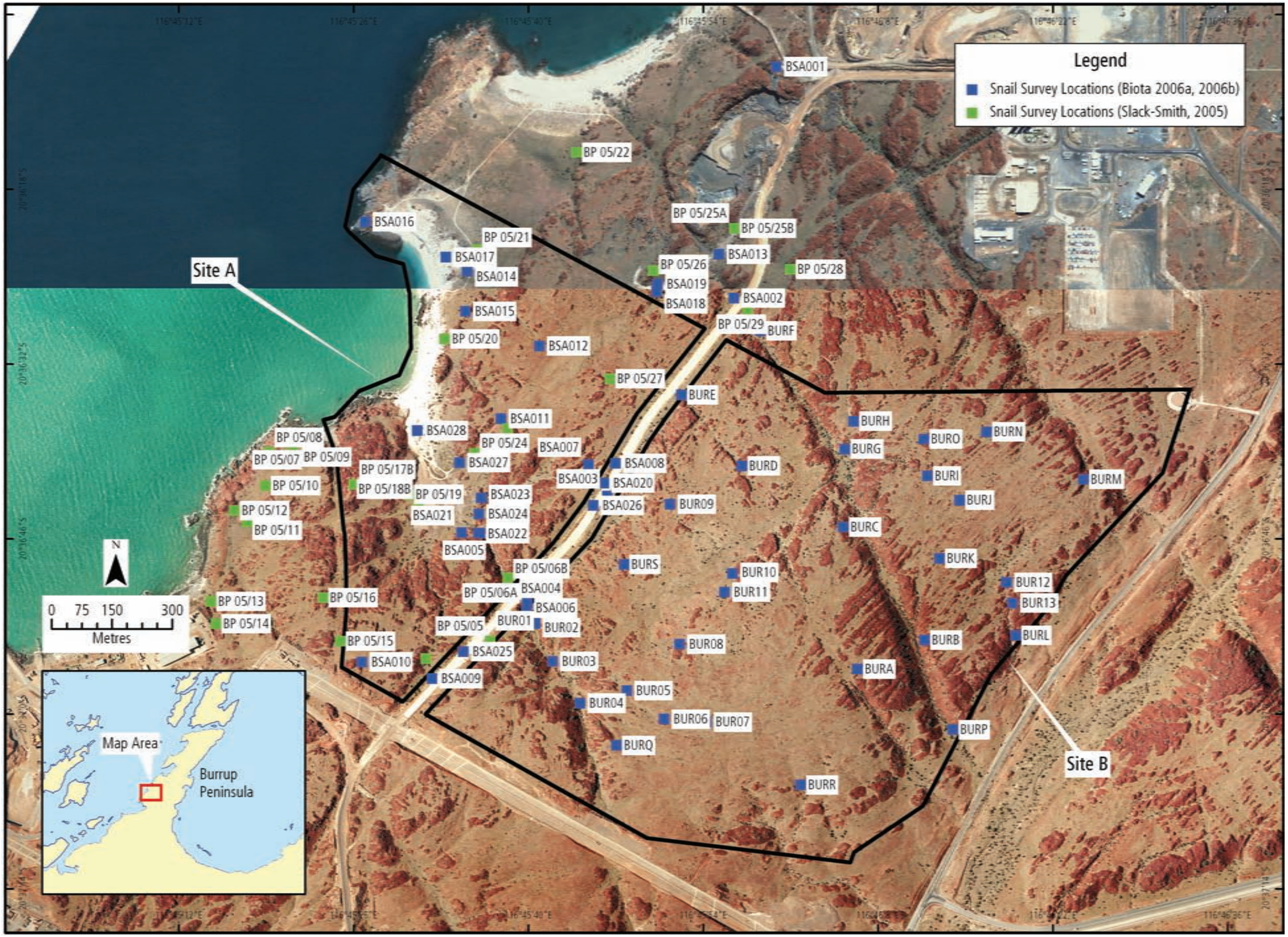
Table 8-13 Aquatic and land Snails recorded within Site A and Adjacent Areas (Slack-Smith 2005)

Survey Area	*Quistrachia legendrei*	*Rhagada* sp.	*Pupoides* sp.? *P. beltianus*	*Pupoides contraries*	*Gastrocopta pilbarana*	*Stenopylis coarctata*	*Amerianna* sp.
Site A	17	28	18	6	19	14	5
Adjacent Areas	25	39	28	7	23	11	0
Total	**42**	**67**	**46**	**13**	**42**	**25**	**5**

Table 8-14 Aquatic and Land Snails Recorded within the Pluto LNG Development and other areas on the Burrup Peninsula (Biota Environmental Sciences 2006a; 2006b)

Survey Area	Land Snails Recorded				Aquatic Snails Recorded
	Live Rhagada snails	Dead *Rhagada*	Live *Quistrachia* snails	Dead *Quistrachia*	Live *Isidorella* snails
Site A	47	394	0	52	0
Site B	49	61	17	19	96
Site E	35	288	0	2	0
Total	**131**	**743**	**17**	**73**	**96**

Figure 8-15 Site B and Site A Snail Survey Sites



Most for the *Rhagada* specimens found in 2006 resembled *Rhagada* sp '12' (banded) which has been recorded elsewhere on the Burrup Peninsula (Biota Environmental Sciences 2006a; 2006b). *Rhagada* sp '12' (banded) was relatively abundant in the three sites. At one location in the north-western part of Site A, the specimens had pale, unbanded shells that differ in colour to the shells of Rhagada sp '12' that has previously been recorded on the Burrup Peninsula (Biota Environmental Sciences 2006a). Genetic analysis was undertaken on the pale *Rhagada* species to determine whether it was a different species (Biota Environmental Sciences 2006a). While only using genetic analysis (in this case analysis of mitochondrial DNA) has limitations in terms of identifying species, the genetic analysis concluded that the specimens had a low level of sequence divergence (as low as 2.4%), are therefore very similar to *Rhagada* sp '12' and are probably a pale form of that species.

Genetic analysis of *Rhagada* sp '12' (banded) found that, although the specimens collected in Site B and Site A look the same and resemble the other specimens collect on the Burrup Peninsula, there were genetic differences between specimens. This was also found to be the case for *Rhagada* sp '12' in other areas of the Burrup Peninsula (industrial Site E, currently vacant). The most likely explanation for the genetic differences is that the *Rhagada* sp '12' has evolved over a history of isolation, divergence and re-invasions on the Burrup Peninsula (Biota Environmental Sciences 2006a). It is likely that, as sea levels fluctuated over time, populations became isolated on areas of high elevation and could not exchange genetic material with other populations. This was followed by periods of lower sea levels (such as the current environment) where populations have slowly re-colonised low-lying areas.

The genetic analysis used mitochondrial DNA, therefore the conclusions are not decisive (Biota Environmental Sciences 2006a). Mitochondrial DNA is only inherited from the female parent (mother), as opposed to nuclear DNA which is inherited from both parents (Dasmahapatra and Mallet 2006). It also evolves faster than nuclear DNA and can behave differently to nuclear DNA. Therefore, mitochondrial DNA analysis can show different DNA results for individuals of the same species if the maternal lineages are different. The only way to resolve the number of *Rhagada* taxa on the Burrup Peninsula is to undertake nuclear analysis and/or conduct mating experiments, both of which require extensive investigations.

Terrestrial Environment Impacts and Management

9

9.1 Summary of Impacts

This section the Draft PER identifies the potential terrestrial impacts from the proposed Pluto LNG Development and associated preventative and management strategies that will be implemented to reduce impacts to an acceptable level.

Activities associated with the Development have been assessed through a comprehensive impact assessment process which has been verified using the Woodside corporate risk assessment tool described in **Section 7.2**. This process allows potential environmental impacts to be systematically identified and considered on the basis of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk to the environment.

It should be recognised that a formal risk assessment of environmental issues is only one of the tools employed to identify and rank the key environmental impacts of the Pluto LNG Development. The value of the risk assessment is as a high-level screening tool, to identify the impacts that require detailed assessment. The results of the risk assessment should not be interpreted in isolation from the broader assessment process described within this Draft PER.

The impact assessment concluded that the vast majority of terrestrial impacts can be categorised as having short-term consequences on the environment and will be managed through the implementation of routine mitigation and management measures. Priority has been given to development of management measures to address the following potential impacts:

- alteration of natural drainage lines within Site B (**Section 9.2.3**)
- vegetation and flora clearing (**Section 9.3.1**)
- introduction or spread of weeds (**Section 9.3.2**)
- disturbance to and loss of fauna habitat (**Section 9.3.3**)
- displacement, injury to or fatality of fauna (**Section 9.3.3**)
- small chemical or hydrocarbon spills (**Section 9.4.3**)
- noise impacts from flaring during gas processing plant commissioning and operation (**Section 9.5.5**).

To address these potential impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to acceptable levels. Key mitigation and management measures include:

- engineering design to minimise alteration of natural drainage within Site B
- evaluation of the Site A and Site B layout options in order to avoid good quality vegetation and significant flora species as much as possible, whilst also minimising cultural heritage impacts
- consultation with the DEC to manage Priority flora
- implementation of a weed monitoring and control program to control the spread of weeds, or introduction of new infestations, within the disturbance footprint and in adjacent areas
- relocation of Pilbara olive pythons found during earthworks by trained handlers
- design and construction of hazardous materials storage facilities and handling equipment to prevent and contain spills
- engineering design to ensure noise levels comply with noise regulations
- blasting during daylight hours to reduce impacts during peak nocturnal fauna activity times (dusk, night, dawn).

With the implementation of the appropriate mitigation and management measures it is not expected that these impacts will result in unacceptable negative impacts on the terrestrial environment.

9.2 Physical Terrestrial Environment

9.2.1 Landforms and Soils

The construction phase of the Pluto LNG Development represents the greatest risk of disturbance to landform features and soils within the Development area. These activities include:

- trunkline trenching
- vehicle movements
- vegetation clearing
- earthworks
- development of stockpiles.

These activities have the potential to result in localised modifications to landforms, and may alter natural erosion and deposition processes, potentially resulting in changes to soil profiles. These physical effects will be exacerbated should ground disturbing construction activities coincide with high rainfall or cyclonic events.

Ongoing operations associated with management and maintenance of the trunkline and gas processing plant facilities will have a very minimal physical impact to landforms and soils and will be limited to vehicle movement associated with routine trunkline inspections.

Erosion and Run-off

Factors that are taken into consideration when assessing erosion and runoff risk include:

- existing erosion areas and sensitive features located within or adjacent to the gas processing plant site and trunkline route
- presence of soil cover (existing and permanent), soil thickness and soil quality
- length and degree (steepness) of slopes to be exposed during construction and remaining during operation
- regional rainfall variability and extreme rainfall events (for example, cyclones)
- the timing of construction activities in relation to the wet and dry seasons.

Van Vreeswyk et al. (2004) concluded that the stony soils and red shallow sands characterised by the Granitic Land System, which encompasses the majority of the Pluto LNG Development, have a low risk rating for water and wind erosion. This is attributed to the protection afforded by abundant stony mantles or crusts (50–90%). However, the potential for erosion varies across different areas of the Pluto LNG Development area due to different soil types, degree of vegetation cover, topography and soil classifications.

Gas Trunkline Option 1

As outlined in **Section 8.2.2**, the majority of the gas trunkline Option 1 is located within the NWSV Karratha Gas Plant lease area on relatively flat, pre-disturbed soils. In addition, the southern section of gas trunkline Option 1 will be laid adjacent to the NWSV Haul Road on relatively flat land, which will limit the potential for erosion and run-off. The potential for erosion and run-off during trenching and installation of the gas trunkline Option 1 is considered to be low.

Gas Trunkline Option 2

Gas trunkline Option 2 comes ashore at Site A, travels along the northern boundary of Site A and then crosses into Site B. As such, impacts are considered as part of the overall works at Site A and Site B below.

Site B

The topography at Site B, which is characterised by an abundance of loose boulder outcrops, rock ridges, upland terraces and deep gullies is considered to represent high erosion and runoff potential. The site ranges in elevation from 30 m to in excess of 80 m AHD. The site consists mainly of alluvial deposits, and soils are generally shallow and underlain by a fractured bedrock basement.

The gas processing plant layout and associated infrastructure at Site B have been located to avoid deep gullies and steep sided slopes as far as reasonably practicable. The majority of the gas processing plant and infrastructure will be located on upland terrace features, although fairly extensive earthworks and removal of soil and rock will be required at the location of the gas processing plant to obtain finished ground levels ranging between 54 m to 60 m AHD. During these activities, site levelling and earthworks have the potential to trigger soil erosion and runoff due to the exposure of previously undisturbed soils and the creation of temporary stockpile areas.

During operation, the extent of off-site erosion to unpaved areas of Site B will be dependant upon the stormwater drainage design. In the event that stormwater drainage is managed inappropriately, the risk of runoff and subsequent erosion from the site is likely to increase.

Site A

The landforms within Site A include steeply inclined gullies which, like Site B, concentrate overland flow and channel it to the lower slopes. The potential for erosion and runoff during construction and operation of the tank storage and export facilities at Site A is likely to be limited, given that all earthworks and installation of pre-construction drainage and associated erosion control measures will be undertaken as part of site preparation works (Woodside 2006a). Alteration of existing erosion and runoff patterns during operational activities is unlikely.

Preventative and Management Measures

Erosion control measures will be implemented, especially during construction activities, and will be detailed in an Erosion and Sediment Control Management Plan (**Table G-8**, **Appendix G**). The erosion control measures will give consideration to rainfall variability and extreme rainfall events (for example, cyclones).

A summary of preventative and management measures is provided in **Table 9-1**.

Residual Risk

The implementation of management and preventative measures is likely to significantly reduce the potential for erosion and runoff events. It is considered that a low residual risk will remain once these measures are implemented.

Soil Compaction

Construction activities have the potential to result in localised soil compaction through heavy vehicle movements, stockpiling of soils and storage of equipment. Compaction of soil has the potential to negatively affect plant root growth, soil moisture potential, soil quality, vegetation establishment, surface and subsurface drainage, runoff and soil erosion.

Many factors can influence soil compressibility and the behaviour of soil under stress. These include:

- extent of ground cover vegetation
- soil particle size, distribution of particles, particle shape and the compressive strength of coarse particles
- homogeneity of the soil profile, the type of clay material present and the presence of cementing agents
- drainage characteristics of the soil, soil moisture content and distribution at the time load is applied (moist soils are generally more easily compressed then dry or wet (saturated) soils).

Preventative and Management Measures

Proposed management measures are summarised in **Table 9-2**.

Residual Risk

The restriction of vehicle movements to designated areas and rehabilitation of compacted areas following construction will reduce the likelihood and consequences of impacts. The residual risk is therefore considered low.

Generation of Acid Sulfate Soils

When exposed to air as a result of drainage or disturbance, Acid Sulfate Soils (ASS) produce sulfuric acid, and often release iron, aluminium and heavy metals. Potential impacts to the environment can include adverse changes to water quality and associated ecological communities.

Table 9-1 Summary of Impacts, Management and Risks of Erosion and Runoff

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Erosion and Runoff	Excavation and 'cut and fill' activities Vegetation clearing Vehicle movements Pipeline trenching Stockpiles	Increased runoff leading to erosion of soil and deposition Creation of unstable soil surfaces/slopes Formation of erosion features such as gullies and rills Soil deposition down gradient of Development sites Adverse changes to surface water quality from elevated levels of silt and suspended materials	An Erosion and Sediment Control Management Plan (**Table G-8**, **Appendix G**) will be developed and implemented, and will include the following: • The total area to be disturbed will be restricted to the minimum area required for the Development. • Runoff control measures will be implemented. • Sediment/silt fences will be installed to trap sediment runoff downstream of construction areas. • Erosion and sediment control structures will be routinely inspected and maintained to ensure they remain effective, including the removal of accumulated silt as required. • Stormwater drainage will be installed at all major storm water outlets within Site A and Site B. A Rehabilitation Management Plan (**Table G-17**, **Appendix G**) will be developed and implemented.	E	3	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Table 9-2 Summary of Impacts, Management and Risks of Soil Compaction

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Soil Compaction	Vehicle and plant machinery movements Equipment storage and stockpiling of soil and rock	Increased surface water runoff due to creation of hard stand surfaces Decreased soil moisture potential Decreased vegetation cover	An Erosion and Sediment Control Management Plan (**Table G-8**, **Appendix G**) will be developed and implemented, and will be based on the following principles: • The total area to be disturbed will be restricted to the minimum area required for the Development. • Movement of vehicles will be restricted to designated roads/tracks, and will adhere to onsite speed limits. A Rehabilitation Management Plan (**Table G-17**, **Appendix G**) will be developed and implemented.	E	4	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Although there is a low likelihood of encountering ASS, some Development areas including areas along the gas trunkline Option 1 and the coastal dunes and sands in the western part of Site A, have been assessed as being of moderate risk (**Section 8.2.3**).

The severity of potential impacts will depend upon a number of factors including:

- The nature of the soil. Soils have varying acid producing potential derived from their texture, pyritic concentration and the amount of natural buffering or neutralising material present in the soil structure. The calcareous nature of the local sands suggests there is a high potential for buffering.
- The period and frequency of ASS exposure.

To reduce the risk of potential impacts from ASS exposure, it will be necessary to accurately identify those areas where ASS are present. Additional ASS desktop investigations will be undertaken prior to construction to determine the specific locations of potential ASS locations within the Development area. This may necessitate subsequent preliminary ASS investigations particularly where tidally influenced soils are encountered in other areas assessed as having moderate or high ASS risk potential.

The investigation will adhere to relevant aspects of the following guidelines where applicable:

- *'Draft Identification and Investigation of Acid Sulfate Soils – Acid Sulfate Soils Guideline Series' (Draft 2006)*, Department of Environment and Conservation, Western Australia.
- *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland* (1998), Department of Natural Resources, Queensland.

Where field testing identifies potential ASS, further laboratory testing will be conducted.

Preventative and Management Measures

Preventative and management measures are outlined in **Table 9-3**.

Residual Risk

With management measures detailed in **Table 9-3**, the residual risk for ASS is considered low.

9.2.2 Hydrogeology

Development on previously un-disturbed land can affect existing hydrologeological conditions in a number of ways including alteration of hydrogeological flow regimes and direction; alteration of groundwater elevation; contamination of groundwater from hydrocarbon spills and leaks and indirect effects on existing groundwater abstraction and user groups.

Alteration of Hydrogeological Conditions

The following construction activities have the potential to increase the rate and volume of recharge water entering the watertable during construction activities:

- clearing of vegetation
- excavation of weathered bedrock and bedrock material
- blasting which has the potential to open up and/or create new joints/fractures in bedrock.

Increased recharge volumes and rates, in turn, may lead to increased hydraulic gradients and increased rates of groundwater flow. In particular, opening up or creating new joints and fractures in the bedrock due to blasting has the potential to alter the direction of groundwater flow on a local scale. Blasting of bedrock is also capable of sealing existing open joints and fractures, thereby blocking existing groundwater pathways. This can lower volumes and rates of groundwater recharge, and in turn lower the watertable levels.

Table 9-3 Summary of Impacts, Management and Risks of ASS

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Acid Sulfate Soils (ASS)	Earthworks associated with construction activities such as land clearing, excavations and trenching (onshore trunklne).	Soil acidification Adverse changes to surface water and groundwater quality Loss of vegetation communities, fauna habitat and flora/ fauna biodiversity	Should detailed geotechnical investigations and further desktop assessment indicate that Acid Sulphate Soils (ASS) are likely to be present within the Development area, a site investigation will be conducted to consider the specific location or locations of disturbance; the nature of disturbance; volume of material to be disturbed and maximum depth of disturbance. Should the results of the investigation indicate ASS are present, then a detailed ASS Management Plan will be developed.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Impacts due to operations will mainly be associated with the presence of infrastructure at Site B and Site A, which can affect recharge potential. For example, site paving will reduce the recharge of rain water into the watertable in areas directly beneath the paving, whilst drainage systems will divert rain water away from some areas and into others.

Interception of Groundwater

The installation of gas trunkline Option 1 is unlikely to encounter groundwater aquifers. Studies at the existing NWSV Karratha Gas Plant, through which the trunkline will be laid, encountered shallow aquifers at 5.12–7.42 mbgs (URS 2004). Any interception of groundwater is expected to occur as seepage.

Geotechnical boreholes drilled at Site B in 1998 (Dames and Moore 1998) did not encounter water within 20 m of the surface. Given that the majority of Site B is above 50 m elevation reaching up to 80 m elevation, it is anticipated that any groundwater aquifers present, would be intercepted at considerable depth. Preliminary ground elevation estimates for the gas processing plant at Site B range between 54 m to 60 m AHD. It is highly unlikely that the construction activities will encounter groundwater aquifers.

Earthworks at Site A will mainly be undertaken during site preparation works (Woodside 2006a). Site A excavation depths for the Pluto LNG Development will be a maximum of approximately 10 mbgs. It is unlikely that groundwater interception will occur in the areas that will be disturbed on Site A due to the corresponding high elevation of these areas.

It is emphasised that any groundwater seepage occurring during the excavation works within the Development area is unlikely to contribute to widespread drawdown of any existing groundwater aquifers. The bedrock is generally a massive, tight rock mass and was a very low transmissivity. Any drawdown cones occurring as a consequence of groundwater seepage are therefore likely to be steep and narrow, and limited in lateral extent.

Groundwater Use

Potential groundwater use throughout the Pluto LNG Development area is severely constrained due to the very low quality and high salinity of the groundwater (in excess of 70 000 µg/cm EC units). This precludes the groundwater from a range of uses including human or livestock consumption and stock, domestic and industrial purposes. In addition, the DEC's groundwater bore database does not reveal any registered boreholes on the Peninsula.

Groundwater Contamination

There is potential for groundwater contamination from leaks or spills associated with chemical, fuel and waste storage and handling, and equipment failure. Potential sources of contamination include:

- leakage of hydrocarbons from on-site machinery (that is, excavators, mobile crushers, trucks and other machinery)
- potential leaks from processing equipment and utility equipment (gas turbines, compressors, pumps)
- loss of containment from condensate storage tanks and associated piping
- leakage of hydrocarbons from the diesel fuel system at Site B
- leakage of contaminated water from the oil-contaminated water system at Site B
- leaks/spills of effluent from the effluent treatment system at Site B
- leakage of hazardous wastes from on-site storage drums and tanks at Site B and Site A
- breakages of hydraulic hoses and fittings
- poor refuelling practices
- blasting powder residue
- washing down of trucks and equipment.

Given the lack of permanent surface water bodies within the Pluto LNG Development area, contamination via groundwater and surface water interaction is unlikely. Instead, the contaminant pathways to the watertable will be via intergranular flow through the weathered bedrock material and/or the open fractures/joints of the granophyre bedrock.

Preventative and Management Measures

The likelihood of spills or leaks will be mitigated through design controls, equipment and plant testing and an inspection and maintenance programme. In addition, chemical and fuel storage and handling procedures and spill response will be documented and implemented through an Onshore Spill Response Plan (**Table G-10**, **Appendix G**) that will cover construction and operation activities. A Waste Management Plan (**Table G-4**, **Appendix G**) and Waste Water Management Plan (**Table G-3**, **Appendix G**) will also be developed to mitigate risks associated with the storage and handling of solid and liquid wastes. A Groundwater and Surface Water Protection Plan (**Table G-9**, **Appendix G**) will be developed and implemented.

Preventative and management measures are summarised in **Table 9-4**.

Table 9-4 Summary of Impacts, Management and Risks of Groundwater Contamination

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Alteration of Hydrogeological Conditions Groundwater Interception	Clearing of vegetation Excavation of weathered bedrock and bedrock material Blasting	Alteration of recharge volumes and rates, watertable levels and/ or groundwater flow	The working area will be clearly delineated on drawings and on the ground to ensure only the minimum area required is cleared. A Groundwater and Surface Water Protection Plan (**Table G-9**, **Appendix G**) will be developed.	D	1	L
Groundwater Contamination	Storage and disposal of liquid and solid wastes Fuel or chemical spill	Reduction in groundwater quality	A Groundwater and Surface Water Protection Plan (**Table G-9**, **Appendix G**) will be developed incorporating the following: • Strict procedures will be implemented to prevent leaks or spills of hydrocarbons. • Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water. • A water monitoring programme will be developed and implemented at Site B and Site A. An Onshore Spill Response Plan (**Table G-10**, **Appendix G**) will be developed based on the following principles: • Site inductions prior to construction activities will include correct materials handling procedures, spill management and spill response procedures. • Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations. Spills will be cleaned up immediately to avoid contamination. Development and implementation of a Waste Management Plan (**Table G-4**, **Appendix G**) that will include measures such as: • Hazardous materials storage facilities and handling equipment will be designed and constructed to prevent and contain spills.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Residual Risk

Implementation of appropriate spill prevention, spill response and waste management measures will reduce the probability of a contamination event occurring. This will reduce the residual risk of groundwater contamination to low.

9.2.3 Hydrology

Alteration of surface water flows associated with earthworks during construction and the presence of infrastructure during operation can result in:

- formation of erosion features such as rills, gullies and embankment erosion
- changes to natural drainage lines resulting in decreased or increased flow of surface water
- re-direction of drainage water to previously undisturbed areas
- sedimentation of surface water features
- surface water ponding
- increased surface water runoff volumes.

The construction and operation activities associated with the Development also have the potential to result in surface water contamination and degradation of water quality due to surface runoff containing contaminants from leaks or spills.

The layout of the gas processing plant at Site B has been designed to avoid disturbance to significant drainage features and gullies that transect the site.

The topographical positioning of the Development footprint will ensure that non-intercepted surface water, exiting by rocky drainage gullies, will flow from the lease into existing vegetation downstream of the lease area. Potential impacts to vegetation include:

- Sedimentation of drainage lines and gullies due to increased erosion: The positioning of the proposed Development along the flanks and heads of gullies in Site B will require significant earthworks and infill resulting in the transport of sediment loads in surface flows downstream.
- Alteration of drainage patterns: Alteration of drainage patterns due to site works can either increase or decrease the amount of water entering drainage lines. Generally surface-water flows into the surrounding vegetated gullies will increase as a result of development due to hard surfaces such as paving and roads that restrict water infiltration. The layout of the Pluto LNG Development within Site B and Site A has taken into consideration the location of the major drainage lines and gullies within the sites, and most drainage lines will be avoided by the Development, therefore it is expected that water flow will not decrease in most drainage lines.
- Spread or introduction of weeds: Water is a very effective dispersal mechanism for seeds, and it is possible that weed species may be introduced or spread down drainage lines due to the transport of equipment and movement of vehicles upslope.

Preventative and Management Measures

Various management plans will be developed and implemented that will include measures to address impacts, including a Groundwater and Surface Water Protection Plan (**Table G-9**, **Appendix G**); an Erosion and Sediment Control Plan (**Table G-8**, **Appendix G**); a Waste Management Plan (**Table G-4**, **Appendix G**); and a Weed Management Plan (**Table G-13**, **Appendix G**). Management measures proposed to address the above impacts are summarised in **Table 9-5**.

Residual Risk

With the implementation of appropriate controls, most of the residual risks to hydrology are considered low.

9.3 Ecological Terrestrial Environment

9.3.1 Vegetation and Flora

Vegetation clearing will be required for the majority of the Pluto LNG Development area. Clearing will have a direct impact on vegetation and flora. Other activities that could have an impact on vegetation and flora include the introduction and spread of weeds, accidental fire and the generation of dust. The following direct and indirect impacts to vegetation and flora will result from clearing activities:

- Loss or damage of protected flora species. Some individual plants of *Terminalia supranitifolia* (Priority 3) will need to be removed from Site B and Site A.
- Loss or damage of regional vegetation associations of conservation significance. A total of 21 regional vegetation associations of conservation significance occur within the Pluto LNG Development area. This includes a total of 12 within the disturbance footprint at Site A and Site B. The total area of each significant association that will be cleared and a comparison to regional coverage as established by Trudgen's (2002) vegetation studies, is given in **Table 9-6**, with the exception of gas trunkline Option 1. Gas trunkline Option 1 is completely degraded, and the area was mapped by Trudgen (2002) as 'disturbed'.
- Loss or damage of potentially locally restricted vegetation associations. A total of 16 potentially restricted associations occur within the Site B disturbance footprint and eight within the Site A disturbance footprint.
- Accidental disturbance of vegetation. Disturbance of vegetation outside the planned disturbance footprint could occur through vehicle and personnel movement outside designated areas, dust deposition or accidental fire. The extent of such impacts could include minor damage to individual plants or damage to a vegetation community.

Table 9-5 Summary of Impacts, Management and Risks of Alteration of Drainage Patterns

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Alteration of Drainage Patterns	Disturbance of vegetation and soils during construction activities	Changes to natural drainage lines Sedimentation of surface water features and drainage lines Surface water ponding Increased surface water runoff volumes	Existing drainage patterns will be maintained as far as practicable. The following EMPs will be developed and implemented to prevent or mitigate impacts: • a Groundwater and Surface Water Protection Plan (**Table G-9**, **Appendix G**) • an Erosion and Sediment Control Plan (**Table G-8**, **Appendix G**). • a Waste Management Plan (**Table G-4**, **Appendix G**).	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

- Potential introduction and spread of weeds (**Section 9.3.2**). Disturbance caused by the removal of native vegetation and earthworks may create conditions suitable for the establishment of weed species. The movement of vehicles and equipment could also result in the introduction of new weed species or the spread of existing weed species by transporting seeds and propagules into or throughout the Development area.

Impacts on Regional Vegetation Associations

Regional analysis of vegetation impacts was undertaken using mapping from Trudgen (2002). **Table 9-6** provides an assessment of the cumulative impacts of vegetation clearing at Site B and Site A.

Clearing along gas trunkline Option 1 poses the least impact as the vegetation within the corridor is already highly disturbed and no regionally significant associations were identified. The small pockets of remnant native vegetation along the trunkline route are not viable in the long term as they occur within developed land and there is a high presence of weeds. All of the species found along gas trunkline Option 1 have been recorded elsewhere on the Burrup Peninsula. Any impacts caused by clearing within the trunkline corridor are therefore considered to be negligible.

Clearing for the gas trunkline Option 2 will be undertaken in conjunction with general clearing within Site A and Site B as discussed below.

Regional analysis of vegetation clearing (**Table 9-6**) indicates that the proposed clearing requirements will not have a significant impact on the distribution of most of the vegetation communities within the Burrup Peninsula. A total of 12 vegetation associations of regional conservation significance will be impacted by clearing associated with the Pluto LNG Development at Site B and Site A. Of these, 10 significant associations will be reduced by less then 20% of their current known extent on the Burrup Peninsula; most of these 10 vegetation associations have some representation in the Burrup Peninsula Conservation Zone with the exception of AcCaTe, CwTe, IcImTe and TeEtSg, which have no representation within the Conservation Zone. Plant species which make up these associations are found elsewhere on the Burrup Peninsula.

Two regionally significant vegetation associations will be cleared by more then 20% of their known extent (as mapped by Trudgen (2002)): AbCc'Te and AcImTe/TeCa. Impacts to AbCc'Te and AcImTe/TeCa will occur at Site B, where AcImTe/TeCa will lose 85.6% of its known extent and AbCc'Te will lose 64.8% of its known extent on the Burrup Peninsula. Furthermore, AcImTe/TeCa has no representation in the Burrup Peninsula Conservation Zone although this vegetation association is a mosaic of the vegetation associations AcImTe and TeCa and both of these vegetation associations have representation in the Conservation Zone (73.9% of AcImTe and 4.3% of TeCa). AbCc'Te has only 19% of its extent in the Burrup Peninsula Conservation Zone. It should be noted that the plant species which comprise these vegetation associations are found elsewhere on the Burrup Peninsula.

Nine regionally significant vegetation associations will have already been affected in Site A by site preparation works (Woodside 2006a): Ac'Te, BaTcTe, CwTe, DsTsTe, IcImTe, R, SgTeTa, TeAb and TeCa. Four of these (Ac'Te, BaTcTe, DsTsTe and SgTeTa) will not be further impacted by the activities associated with the Pluto LNG Development as described in this Draft PER. However, of the aforementioned vegetation associations, the development will affect vegetation associations CwTe, IcImTe, R, TeAb and TeCa. Vegetation association GpImTe was not affected by the Site A perparation works (Woodside 2006a); however, it will be impacted upon by the activities described in this Draft PER.

Other habitats that support vegetation considered to be of conservation significance on a Burrup Peninsula scale are coastal sands and dunes, samphire areas, rockpiles and drainage lines (McKenzie et al. 2003; Astron Environmental 2005a; ENV 2006a). These were outside the scope of Trudgen's (2002) study; therefore, detailed mapping of vegetation at a regional scale within these habitats is not available. Trudgen (2002) did provide broad-scale mapping of samphire and rockpile areas; however, these two groups do not account for the diversity of vegetation communities found within samphire and rockpile areas. No samphire vegetation will be affected, however rockpile habitats will be disturbed within the Pluto LNG Development area as follows:

- Site B: approximately 11.3 ha of rockpile habitat will be disturbed
- Site A: approximately 0.77 ha of rockpile habitat will be disturbed

As discussed in **Section 8.3.2**, not all vegetation associations described at a local scale by surveys conducted for this Draft PER are comparable to the regional vegetation information available. A discussion of vegetation associations that cannot be compared to Trudgen (2002) is included later in this section.

Where local vegation associations cannot be easily compared to vegetation associations mapped by Trudgen (2002), the extent beyond the site within which it was recorded is unknown and therefore assumed to be potentially restricted.

Impacts on Local Vegetation Associations

Gas trunkline Option 1 was surveyed by ENV (2006b). Some small areas of remnant vegetation were recorded; however, this vegetation was completely degraded or in poor condition and therefore considered to have little or no conservation value. As no vegetation associations were recorded, no further analysis has been undertaken to determine impacts on local vegetation associations.

Table 9-6 Pluto LNG Development Approximate Clearing Requirements for Vegetation Associations identified by Trudgen (2002)

Conservation Significant Vegetation Associations	Total Area in Burrup Peninsula (ha)	Area in Conservation Zone (ha)	Area in Conservation Zone (%)	Total Area in Pluto LNG Development (Prior to Clearing)			Area to be cleared for Pluto LNG Development			Previous Clearing in Site A[1] (ha)	Cumulative Area to be cleared in Burrup Peninsula (ha)[5]	Cumulative Area to be cleared in Burrup Peninsula (%)[5]	Area Remaining in Burrup Peninsula after clearing (%)
				Site B (ha)	Site A (ha)	Total (Site B and Site A) (ha)	Site B (ha)	Site A (ha)	Total (Site B and Site A) (ha)				
AbCc'Te	0.68	0.13	19.0	0.55	0	0.55	0.44	0	0.44	0	0.44	64.8	35.2
AbCwTe	64.52	3.31	5.1	0.004	0	0.004	0	0	0	0	0	0.0	100.0
AcCaTe	3.48	0	0	0.5	0	0.5	0.07	0	0.07	0	0.07	1.9	98.1
AcImTe/TeCa	0.90	0	0	0.9	0	0.9	0.8	0	0.8	0	0.8	85.6	14.4
Ac'Te	3.02	0.49	16.3	0	0.98	0.98	0	0	0	0.007	0.007	0.2	99.8
AiFdTe	16.8	2.00	11.9	0.3	0	0.3	0.02	0	0.02	0	0.02	0.1	99.9
BaTcTe	1.80	1.41	78.2	0	0.4	0.4	0	0	0	0.2	0.2	11.4	88.6
CwTe	13.91	0	0	0	3.1	3.1	0	0.86	0.86	0.5	1.4	9.9	90.1
DsTsTe	1.08	1.02	94.4	0	0.05	0.05	0	0	0	0.003	0.003	0.3	99.7
GpImTe	14.21	9.10	64.0	0	0.088	0.088	0	0.007	0.007	0	0.007	0.1	99.9
IcImTe	0.23	0	0	0	0.04	0.04	0	0.005	0.005	0.04	0.04	19.0	81.0
R[2]	2068.25	1716.59	83.0	36.01	18.8	54.8	11.4	0.18	11.5	2.57	14.1	0.7	99.3
SgTeTa	2.15	1.13	52.4	0	0.15	0.15	0	0	0	0.15	0.15	7.0	93.0
Sm[3]	99.82	56.59	56.7	0	0.82	0.82	0	0	0	0	0	0	100
Sv	1.08	0.43	40.3	0	0.56	0.56	0	0	0	0	0	0	100
TcCvSe	0.95	0.23	23.7	0.014	0	0.014	0	0	0	0	0	0	100
TeAb	85.20	14.02	16.5	0	3.13	3.13	0	1.98	1.98	0.61	2.6	3.0	97.0
TeCa	36.09	1.54	4.3	4.33	6.17	10.5	0.57	0.16	0.7	4.08	4.8	13.3	86.7
TeEtSg	1.16	0	0	0.58	0	0.58	0.12	0	0.12	0	0.12	10.4	89.6
TeRm	51.74	10.36	20.0	0.14	0.18	0.32	0.08	0	0.08	0	0.08	0.2	99.8
Ts'Ac'Te	0.36	0	0	0	0.08	0.08	0	0	0	0	0	0	100
Vegetation Associations not Considered Significant[4]	5235.71	3368.68	64.3	85.4	23.32	108.7	52.72	0.86	53.6	9.76	63.3	1.2	98.8

Note 1: This analysis assumes that vegetation clearing within Site A has been undertaken for site preparation works outlined in Woodside (2006a).It does not allow for any previous clearing within Site B.

Note 2: 'R' (rockpile vegetation) was outside Trudgen's (2002) scope of work but has since been determined to be of regional significance.

Note 3: 'Sm' (samphire vegetation) was outside Trudgen's (2002) scope of work but has since been determined to be of regional significance.

Note 4: 'Other vegetation associations' are not considered to be of conservation significance

Note 5: Cumulative Area to be cleared is the sum of clearing proposed for the Pluto LNG Development (Site B and Site A) and Previous Clearing in Site A (Woodside 2006a).

Impacts on local vegetation associations within the gas trunkline Option 2 have been considered within clearing requirements for Site A and Site B, as discussed below.

Astron Environmental (2005a; 2005b) and ENV (2006a) identified local vegetation associations within the disturbance footprint at Site B and Site A. Where a local vegetation association cannot be easily compared to Trudgen's (2002) regional vegetation associations, it is regarded as being potentially locally restricted because there is limited information on its occurrence and distribution throughout the Burrup Peninsula. Local vegetation associations that are considered to be potentially restricted and occur within the Pluto LNG Development disturbance footprint are shown in **Table 9-7**.

As shown, most vegetation associations will not be cleared by more than 63% of the vegetation associations' coverage, within the Pluto LNG Development area. However, CpTaCv in Site B South (Astron Environmental 2005b) and AcAeTe in Site A (Astron Environmental 2005a) will be significantly impacted by the Pluto LNG Development. The extent of clearing is based on a preliminary design, and investigations are continuing to avoid significant impacts to vegetation where possible.

Full descriptions of the vegetation associations, including floristic composition as recorded during field surveys, are provided in Astron Environmental (2005a; 2005b) and ENV (2006a).

The vegetation association CpTaCv, as mapped by Astron Environmental (2005b) in Site B South, will be completely cleared within Site B. It contains three species considered to be of conservation significance by Trudgen (2002). *Triumfetta appendiculata* (Burrup form), *Triodia epactia* (Burrup form) and *Corchorus walcottii* are all regarded as 'locally very common to abundant and moderately restricted'. These three species have been recorded throughout the Burrup Peninsula (Trudgen 2002) and are well represented in the Conservation Zone. A fourth species recorded in vegetation association CpTaCv, *Cullen pustulatum*, was only recorded in one other association within Site A and was identified by Trudgen (2002) in six quadrats on the Burrup Peninsula. However, this species is not considered to be of conservation value by Trudgen (2002) and it is found in other areas of the Pilbara. Other flora species recorded in CpTaCv, such as *Amaranthus pallidiflorus*, *Cleome viscose* and *Trachymene oleracea* are not of conservation value (Astron Environmental 2005b).

The vegetation association AcAeTe, as described by Astron Environmental (2005a), will be almost completely cleared within Site A. There is one 'locally very common to abundant and moderately restricted' species (Trudgen 2002) present in AcAeTe: *Triodia epactia* (Burrup form). As discussed above, this species is common on the Burrup Peninsula (Trudgen 2002) and is represented in the Conservation Zone. It was also recorded in multiple associations across Site A (Astron Environmental 2005a), including vegetation associations outside the disturbance footprint. The weed species *Aerva javanica* is present in AcAeTe. Other species recorded in vegetation association AcAeTe, such as *Rhagodia eremea*, *Amaranthus pallidiflorus*, *Ptilotus villosiflorus*, *Acacia bivenosa* and *Acacia coriacea* occur within the Pilbara region and other areas of Western Australia.

As mentioned above and in **Section 8.3.2.3**, local vegetation associations are considered to be potentially locally restricted

Table 9-7 Potentially Locally Restricted Vegetation Associations within Site B and Site A Disturbance Footprints

Site	Vegetation Association	Total Coverage Within Each Site (ha)	Area to be Cleared Within Each Site (ha)	% to be Cleared Within the Development area
Site B South	BaTsFv	6.13	0.77	12.5%
	ChCwTe	0.15	0.06	42.7%
	CpTaCv	0.10	0.10	100%
	SgTaCv	0.17	0.05	28.7%
	TcFvAc	3.42	2.16	63.3%
	TcBaTeCa	4.13	1.24	30%
	TsBaCpTe	1.53	0.16	10.2%
Site B North	BaTcAcPtTe	27.96	9.72	34.8%
	TcBaRmPtTa	0.76	0.01	1.2%
	TcRmTe	1.43	0.46	32.4%
Site A	AcAeTe	0.162	0.13	82%
	AcIcRm	0.599	0.08	12.8%
	BaTsAc1	16.77	2.5	14.9%
	TapTe	0.078	0	0
	TsAcAe1	1.696	0.33	19.2%

Note 1: Includes vegetation cleared during site preparation works for Site A (Woodside 2006a)

when they cannot be easily compared to regional vegetation associations mapped by Trudgen (2002) as this makes it difficult to ascertain whether similar vegetation associations occur outside the sites surveyed.

Impacts on Significant Flora

No Declared Rare Flora as per the *Wildlife Conservation Act 1950* (WA), or endangered or vulnerable species pursuant to s178 of the EPBC Act, were identified during field surveys of the Pluto LNG Development areas.

One Priority 3 flora species was located within the disturbance footprint of the Pluto LNG Development area: *Terminalia supranitifolia*.

Terminalia supranitifolia has been recorded elsewhere on the Burrup Peninsula, on nearby islands and on the mainland south of the Peninsula; at least 289 individual GPS locations for this species have been recorded on the Burrup Peninsula. The Pluto LNG Development disturbance footprint will impact on some *Terminalia supranitifolia* plants; however due to the number of plants outside the disturbance area impacts are not considered significant.

A total of 16 other flora species that are not protected by legislation but are considered to be of conservation interest were recorded in the Pluto LNG Development area (**Table 9-8**). Most of these species are not unique to the Pluto LNG Development area, but have been recorded at least 50 times in other areas of the Burrup Peninsula and nearby islands, and many are represented in the Burrup Peninsula Conservation Zone (Astron Environmental 2005a; Astron Environmental 2005b; Biota 2002; Trudgen 2002).

As demonstrated in **Table 9-8**, many of the species have been recorded numerous times on the Burrup Peninsula, with some species being recorded over 100 times. These species are considered locally common to locally very common, and occur many times outside of the Pluto LNG Development area.

Species within the Pluto LNG Development area that are very restricted on the Burrup Peninsula are *Euphorbia* sp. (D105-1), *Sida* aff. *cardiophylla* (B22-37) and *Sida* aff. *fibulifera* (B64-13B). These species have been recorded less then 10 times on the Burrup Peninsula (**Table 9-8**). In addition to these, *Dodonea coriacea* has not been recorded on the Burrup Peninsula since 1979 (Astron Environmental 2005b). Impacts to some of these restricted species will be avoided in some areas, for example, *Euphorbia* sp. (D105-1) and *Sida* aff. *cardiophylla* (B22-37) were recorded within Site A but occur outside the disturbance footprint for this site.

Table 9-8 Flora of Conservation Value within the Pluto LNG Development Area

Flora Species	Gas Trunkline Option 1	Site B	Site A	Total Records on the Burrup Peninsula[1]
Corchorus walcottii	X	X	X	181
Dodonea coriacea		X		ID[2]
Euphorbia aff. *drummondii*			X	ID[3]
Euphorbia sp. (*aff coghlanii*)		X		ID[3]
Euphorbia sp. (D105-1)			X	7
Euphorbia tannensis subsp *eremophila* (Burrup form)		X	X	61
Fimbristylis aff. *dichotoma* (M75-4)		X		21
Paspalidium tabulatum (Burrup form)		X	X	149
Rhynchosia sp. *Burrup* (82-1C)		X	X	83
Sida aff. *cardiophylla* (B22-37)		X	X	2
Sida aff. *fibulifera* (B64- 13B)	X			9
Themeda sp. Burrup (84)		X	X	98
Triodia angusta (Burrup form)		X	X	109
Triodia epactia (Burrup form)	X	X	X	300
Triodia wiseana (Burrup form)			X	28
Triumfetta appendiculata (Burrup form)		X	X	176

Note 1: The number of records includes records from the following surveys within the Burrup Peninsula: Astron Environmental (2005a; 2005b), Bennett Environmental Consulting Pty Ltd (2002); Biota (2002); ENV (2006a; 2006b) and Trudgen (2002).

Note 2: Insufficient data. Not recorded since 1979 (Astron Environmental 2005a)

Note 3: Insufficient data. Could be any one of the Euphorbia species recorded by Trudgen (2002) (Astron Environmental 2005a)

Preventative and Management Measures

The following factors, which relate to the 'Environmental Protection of Native Vegetation in Western Australia Position Statement No. 2' (EPA 2000), have been taken into consideration:

- The initial site selection process for the proposed development (**Section 3.2**) resulted in the selection of Site B and Site A as the preferred sites for the gas processing plant and associated infrastructure. Site B and Site A lie within a designated industrial area and thus avoid vegetation within the Burrup Peninsula Conservation Zone and non-industrial areas of the Peninsula.
- Several layout options within the Pluto LNG Development area were evaluated, with the preferred layouts being selected in order to avoid good quality vegetation and significant flora species as much as possible, whilst also minimising cultural heritage impacts.

A Terrestrial Vegetation and Flora Management Plan (**Table G-11**, **Appendix G**) will be developed in consultation with the DEC and implemented during construction. The Plan will address all the potential vegetation and flora risks identified and will include measures as per **Table 9-9**.

Dust measures (**Section 9.5.3**) will be incorporated in a Dust Management Plan (**Table G-14**, **Appendix G**) and fire control measures will be incorporated into the Terrestrial Vegetation and Flora Management Plan (**Table G-11**, **Appendix G**). A Weed Management Plan will be developed and implemented as discussed in **Table G-13**, **Appendix G**.

Rehabilitation of temporary areas, such as laydown areas, access tracks and trunkline working width, will be undertaken in accordance with a Rehabilitation Management Plan (**Table G-17**, **Appendix G**).

Proposed preventative and management measures are summarised in **Table 9-9**.

Residual Risk

The implementation of a Terrestrial Vegetation and Flora Management Plan and other management measures will not reduce the likelihood of vegetation disturbance occurring; however, it may reduce the overall extent of the disturbance. Due to the permanent removal of vegetation of conservation significance, the consequence is considered moderate and the residual risk is high.

Table 9-9 Summary of Impacts, Management and Risks of Vegetation and Flora Impacts

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Vegetation and Flora	Direct disturbance and vegetation clearing Vehicle and personnel movement outside designated areas Generation of dust Fire Introduction of weeds	Decrease in species abundance Fragmentation of vegetation communities Loss or damage of protected flora species within disturbance area, including Priority 3 species *Terminalia supranitifolia* Reduction in area or damage of vegetation associations of conservation significance.	A Terrestrial Vegetation and Flora Management Plan (**Table G-11**, **Appendix G**) will be developed and implemented, and will include the following requirements: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Access for vehicles and machinery will be along designated access tracks and parking areas. • The DEC will be consulted regarding the development of suitable management procedures for Priority flora. • All personnel will be required to undertake an induction, which will include details on the importance of vegetation and flora protection. Dust control measures will be incorporated into the Dust Management Plan (refer to **Section 9.5.3**). Fire control measures will be incorporated into the Vegetation and Flora Management Plan. A Weed Management Plan will be developed and implemented as discussed in **Section 9.3.2**. A Rehabilitation Management Plan (**Table G-17**, **Appendix G**) will be developed and implemented, incorporating the following principle: • Vegetative matter and topsoil cleared from the working areas will be stockpiled for use in rehabilitation.	C	5	H

**C – Consequence; L – Likelihood; RR – Residual Risk*

9.3.2 Weeds

Environmental weeds are defined as plants that establish themselves in natural ecosystems (marine, aquatic and terrestrial) and proceed to modify the natural environment (CALM 1999). Weeds compete with native plants for resources such as water, nutrients and sunlight, and the associated modification to the natural environment can result in adverse effects on fauna habitat as well as loss of native vegetation biodiversity.

The greatest risk of weeds being introduced and spread will occur during vegetation clearing and as a result of the large numbers of vehicles and plant moving in and out of the Development area. Activities that disturb native vegetation create suitable conditions for weeds to rapidly establish and develop into infestations that are then difficult to manage and compete with native vegetation.

Four weed species have been identified in the Development area, with the most common species being kapok (*Aerva javanica*) and buffel grass (*Cenchrus ciliaris*). Kapok was recorded within gas trunkline Options A(1), Site B and Site A, including a dense infestations along gas trunkline Option 1 and at Site A. Buffel grass was recorded at Site B and Site A, but not along gas trunkline Option 1. Other weeds species were only recorded infrequently, occurring at one or two locations within the Pluto LNG Development area (**Section 8.3.5**). The movement of vehicles and plant has the potential to spread these weed species within the Development area and can also result in the introduction of new weeds to the area if equipment is not appropriately inspected and cleaned prior to arrival on site. This is particularly an issue along the gas trunkline Option A(1), where vehicle travel along the corridor has the potential to spread weeds over a large area.

Preventative and Management Measures

Proposed preventative and management measures to address the above impacts are summarised in **Table 9-10**.

Residual Risk

The residual risk associated with weed impacts is considered to be medium.

9.3.3 Fauna Habitats and Species

The potential impacts on fauna and their habitats will include:

- Direct disturbance to and loss of fauna habitat. The removal of breeding, nesting and foraging habitats will result in decreased resources for fauna and may result in habitat fragmentation. The magnitude of barrier effects due to habitat fragmentation will depend on species behaviour and mobility (Goosem et al. 2001) with less mobile fauna being confined to remaining pockets of vegetation. Localised habitat loss for short range land snails will occur, however land snail habitat is not unique to the Pluto LNG Development area.
- Fauna mortality and injury. Increased fauna injury or mortality can occur from traffic movement and from accidental capture in open excavations (e.g. trenches). Animals that are trapped in trenches are exposed to various factors such as stress, predators, effects from the sun and subsequent dehydration (Woinarski et al. 2000). Loss of some individual short range land snails will occur in localised areas, however land snails have been recorded outside the Pluto LNG Development disturbance areas. Fauna mortality as a result of entrapment will be minimised through measures to facilitate escape or removal.

Table 9-10 Summary of Impacts, Management and Risks of Weed Infestations

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Introduction and spread of weeds	Vehicle and plant movement. Transport of construction materials on and off sites.	Competition with native vegetation for resources such as light and water. Degradation of vegetation communities. Proliferation of existing introduced species.	A Weed Management Plan (**Table G-13**, **Appendix G**) will be prepared and implemented, and will include procedures to: • identify and assess controllability of existing weed infestations • establish and maintain plant, vehicle and equipment hygiene to prevent introduction and transfer of weeds • monitor weeds during site preparation works/ construction and operations. • implement weed control methods to manage any new weed infestations during construction and operations, where they can be effectively controlled.	C	3	H

**C – Consequence; L – Likelihood; RR – Residual Risk*

- Direct disturbance to and loss of fauna habitat supporting protected fauna. Some of the fauna habitats within the Pluto LNG Development are used by protected or priority fauna species, these habitats are identified in **Section 8.3.6**. In particular, clearing of rockpiles, rocky slopes and outcrops will affect the Pilbara olive python (*Liasis olivaceus barroni*), which is considered Vulnerable under the EPBC Act 1999 and rare (Schedule 1) under the *Wildlife Conservation Act 1950* (WA). Relocation of the Pilbara olive python will be undertaken by trained snake handlers, and snakes will be released in consultation with the DEC. Pilbara olive pythons are wide-ranging and do not defend their territory; during radio tracking of pythons a number of snakes have been found in a one-kilometre square area (Natural Heritage 2001). Therefore relocation of pythons is not expected to impact upon individuals or populations. Priority fauna species likely to be affected by clearing of fauna habitat are the bush stone-curlew (*Burhinus grallarius*), Australian bustard (*Ardeotis australis*), grey falcon (*Falco hypoleucos*) and the eastern curlew (*Numenius madagascariensis*). Most of these species are highly mobile, have a wide distribution and use a wide range of habitats, therefore they are not reliant upon habitats within the proposed disturbance areas and impacts will be minimal.
- Protected fauna mortality and injury. Of the protected fauna species identified in **Section 8.3.7** as potentially occurring within the Development area, the Pilbara olive python is most likely to be impacted by construction works, as it inhabits rocky areas. This python is protected under both the EBPC Act and the *Wildlife Conservation Act 1950* (WA), and has been recorded throughout the Burrup Peninsula as well as in other areas within the Pilbara region. Green turtles and flatback turtles utilising the beach at Holden Beach, Site A, may be discouraged from nesting during earthworks (**Section 7.6**). Both of these species are protected by the EPBC Act and the *Wildlife Conservation Act 1950* (WA). Nesting effort on beaches within the Development area is low, and the beach does not represent a significant rookery on either a local or regional scale. Other species protected under the EPBC Act and the *Wildlife Conservation Act 1950* (WA) that have been identified as potentially occurring within the Development area have either not been recorded on the Burrup Peninsula, such as the western pebble mound mouse (*Pseudomys chapmani*) and northern quoll (*Dasyurus hallucatus*), or are highly mobile species with a wide distribution, for example the bush stone-curlew and the peregrine falcon.
- Indirect impacts on fauna may occur due to noise, light and predation from introduced species. Fauna inhabiting the area may be disturbed by noise from vehicular movement, earthworks and other human activities. Short-term displacement of fauna is likely to occur in and adjacent to the Development area; however, animals are likely to return once the disturbance has ceased. Lighting can attract some species, for example insects, and can also result in disorientation of turtle hatchlings and birds. Lighting impacts on turtles are addressed in **Section 7.6**.

Preventative and Management Measures

Proposed preventative and management measures are summarised in **Table 9-11**.

Residual Risk

Permanent loss of fauna habitat will occur during construction, however, given the relatively small area of disturbance in relation to surrounding habitat, the residual risk is considered medium. Potential impacts from fauna mortality and injury are also considered a medium risk (potential impacts to sea turtles are considered low risk).

9.4 Waste

9.4.1 Non-Hazardous Waste Stream

Potential Impacts

As discussed in **Section 5.3**, the majority of non-hazardous wastes will be generated during the construction and installation activities. During these activities, large volumes of non-hazardous waste will be generated along the trunkline corridor and at Site B and Site A. Waste will also be generated during operations.

The inappropriate handling, storage and management of non-hazardous waste can lead to various adverse environmental impacts including:

- potential contamination of soils and groundwater
- entanglement or ingestion of waste by local wildlife, which may result in injury or death
- fire hazard
- impacts on visual amenity (for example, litter if poor housekeeping is maintained)
- generation of odour
- attraction of vermin.

Preventative and Management Measures

A Waste Management Plan will be developed and implemented to ensure that waste is disposed of appropriately. An inventory of waste volumes and types will be maintained as part of the plan, and an emphasis will be placed on good housekeeping throughout the various stages of the Development.

Wherever possible, non-hazardous wastes will be reduced, reused and recycled. For waste that cannot be recycled, landfill sites will be identified and consultation sought with regulatory authorities and landfill operators to ensure the existing facilities have the capacity for waste associated with the Pluto LNG Development.

The management measures proposed will also be effective in mitigating against potential cumulative impacts as a results of non-hazardous waste generated during site preparation at Site A (Woodside 2006a).

Table 9-11 Summary of Impacts, Management and Risks of Fauna Impacts

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Fauna	Vegetation clearing. Excavation and trenching activities during trunkline construction. Vehicle and traffic movement	Loss of fauna habitat including removal of breeding, nesting and foraging habitats. Fauna mortality and injury. Protected fauna mortality and injury, including the Pilbara olive python (*Liasis olivaceus barroni*). Short-term disturbance / displacement of species Predation from introduced species.	A Terrestrial Fauna Management Plan (**Table G-12**, **Appendix G**) will be developed and implemented, and will include procedures to ensure that: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Traffic is kept to designated tracks and drivers will abide by the allocated speed limit to minimise fauna fatality or injury by moving vehicles. • All domestic animals will be prohibited from the Development area. • Measures will be in place to protect the Pilbara olive python, including relocation of Pilbara olive pythons found during earthworks by trained handlers.	D	5	M

**C – Consequence; L – Likelihood; RR – Residual Risk*

Proposed preventative and management measures are summarised in **Table 9-12**.

Residual Risk

The potential for impacts to occur can be successfully reduced through the successful implementation of a Waste Management Plan and associated procedures. Residual risks are considered low

9.4.2 Hazardous Waste Streams

Potential Impacts

Hazardous wastes are those that pose a risk to health, safety or the environment if not handled, stored or disposed of correctly. Potential hazardous wastes that may be generated by the Pluto LNG Development are discussed in **Section 5.3**. Environmental impacts from the incorrect management of hazardous wastes include soil and groundwater contamination and impacts on local flora and fauna.

The environmental impact of the disposal or recycling of small volumes of hazardous waste at approved onshore facilities will result in a negligible to slight incremental increase in the environmental impacts associated with these facilities. Spills of hazardous wastes are discussed in **Section 9.4.3**.

Preventative and Management Measures

A Waste Management Plan (**Table G-4**, **Appendix G**) will be developed and implemented to ensure appropriate management of hazardous wastes. An Onshore Spill Response Plan (**Table G-10**, **Appendix G**) will be developed and implemented, and will provide emergency response procedures in the event of a hazardous waste spill. The management measures proposed will also be effective in mitigating against potential cumulative impacts as a result of hazardous waste generated during site preparation at Site A (Woodside 2006a).

The gas processing plant will contain a mercury removal unit (**Section 4.7.3**). The unit is a vessel containing activated carbon beds which absorb mercury contained with the gas. The carbon beds and catalysts will require periodic removal and return to the supplier for recycling, or alternatively will require disposal at an existing, approved hazardous waste reception facility.

Preventative and management measures are summarised in **Table 9-13**.

Residual Risk

The successful segregation, management and safe disposal of hazardous wastes means that residual risks are considered low.

Table 9-12 Summary of Impacts, Management and Risks of Non-Hazardous Waste Stream

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Non-Hazardous Waste Stream	Generation, storage and transport of non-hazardous waste Waste disposal	Attraction of pest species Generation of odours	A Waste Management Plan (**Table G-4**, **Appendix G**) will be developed and will include the following requirements: • Recycling bins will be located in strategic locations around site to facilitate segregation of waste, diverting recyclable solid waste streams from landfill. • All domestic waste will be stored in clearly marked skips and waste containers will be provided throughout construction and operational sites. • Green waste will be segregated from other waste streams. The material will be mulched and reused on site if practicable. • Contractors will be required to place a high emphasis on housekeeping and all work areas will be required to be maintained in a neat and orderly manner.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Table 9-13 Summary of Impacts, Management and Risks of Hazardous Wastes

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Hazardous waste	Generation of hazardous wastes, handling, storage, transport and treatment or disposal.	Contamination of soil Contamination of groundwater, surface water or the terrestrial environment	A Waste Management Plan (**Table G-4**, **Appendix G**) will be developed, incorporating the following principles: • All hazardous waste materials will be documented and tracked, segregated from other waste streams and stored in suitable containers. • The carbon beds and catalysts from the gas processing plant will either be returned to the supplier for recycling or will require disposal at an existing, approved hazardous waste reception facility. • All hazardous materials will be handled and stored in accordance with the corresponding MSDS and Australian Standards. • Hazardous materials storage facilities and handling equipment will be designed and constructed to prevent and contain spills. • Recyclable hazardous wastes will be segregated from other waste materials while non-recyclable hazardous wastes will be disposed of at an approved facility. An Onshore Spill Response Plan (**Table G-10**, **Appendix G**) will be implemented and developed to include: • Prior to the commencement of construction activities, appropriate and specific strategies and actions will be identified for spill events. Responsibilities for action, notification and reporting will also be identified. • Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations. Spills will be cleaned up immediately to avoid contamination.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

9.4.3 Non Routine Discharges

Potential Impacts

Fuel and other hazardous materials required will be stored on the site prior to use. Products such as condensate will also require storage in custom designed tanks during operation, prior to export. These materials and products have the potential to result in non routine contaminated water or AOC water (**Section 5.2.15**). Impacts relating to the discharge of treated non routine contaminated water and AOC water are discussed in **Section 7.8.13**.

Spills of large volumes, or spills in close proximity to site boundaries, have the following potential impacts:

- soil, groundwater and surface water contamination
- death or injury to fauna
- damage to vegetation.

Process-generated liquids from the AOC water system are generated in higher volumes than other hazardous wastes and have the potential to pollute large areas if poorly managed. The impacts of such contamination events would vary depending on the location, type of spill and concentration of contaminants. Detailed design of the Pluto LNG Development drainage systems will investigate and incorporate design aspects to minimise the risk of contamination of the environment from spills.

Preventative and Management Measures

A Waste Management Plan (**Table G-4**, **Appendix G**) and Onshore Spill Response Plan (**Table G-10**, **Appendix G**) will be developed and implemented; the latter will include reference to relevant spill prevention and management procedures.

The management measures proposed will also be effective in mitigating against potential cumulative impacts as a result of non-routine discharges generated during site preparation at Site A (Woodside 2006a).

Preventative and management measures are described in **Table 9-14**.

Table 9-14 Summary of Impacts, Management and Risks of Non-Routine Discharges

<table>
<tr><th rowspan="2">Aspect</th><th rowspan="2">Activity, Event or Source</th><th rowspan="2">Affected Environment or Impact</th><th rowspan="2">Mitigation/Control Measure</th><th colspan="3">Residual Risk</th></tr>
<tr><th>C</th><th>L</th><th>RR</th></tr>
<tr><td rowspan="2">Non-routine Discharges</td><td>Large spills (for example, an overturned road tanker: spillage of approximately 220,000L of fuel).</td><td>Soil contamination
Groundwater and surface water contamination
Death or injury to fauna</td><td rowspan="2">A Waste Management Plan (Table G-4, Appendix G) will be developed and implemented to include the following:
• All hazardous materials will be handled and stored in accordance with the corresponding MSDS and Australian Standards.
• Hazardous materials storage facilities and handling equipment will be designed and constructed to prevent and contain spills.
• Appropriate controls on the AOC water system to enable isolation of spill events to prevent contamination of large volumes of liquid, and facilitating extraction of specific contaminated liquids.
A Groundwater and Surface Water Protection Plan (Table G-9, Appendix G) will be prepared and implemented, and will incorporate the following principles:
• Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water.
An Onshore Spill Response Plan (Table G-10, Appendix G) will be developed and implemented; this will include reference to relevant spill prevention and management procedures and will incorporate the following:
• Site inductions prior to construction activities which will include correct materials handling procedures, spill management and spill response procedures.
• Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations. Spills will be cleaned up immediately to avoid contamination.</td><td>C</td><td>0</td><td>L</td></tr>
<tr><td>Small spills (for example, during refuelling: litres (tens))</td><td>Soil contamination
Groundwater and surface water contamination
Death or injury to fauna</td><td>D</td><td>4</td><td>M</td></tr>
</table>

**C – Consequence; L – Likelihood; RR – Residual Risk*

Residual Risk

The likelihood of a large onshore spill event occurring is remote and the consequences moderate. The risk is therefore considered low. Risks from small spills are considered medium as although they are likely to occur the consequence will be minor. The residual risk is considered to be medium.

9.5 Emissions

9.5.1 Combustion Products

This section provides a summary of the key information provided in the detailed air quality assessment undertaken by SKM (2006a).

The most significant air emissions from the Pluto LNG Development in terms of potential air quality impacts will be from the combustion of natural gas in the gas turbines and from flaring events associated with the gas processing plant, and in particular during commissioning when flaring will occur continuously for up to approximately six months (**Section 5.1.2**). The key air pollutant species for existing sources plus the proposed Pluto LNG Development sources in relation to highest risk of impacts on ambient air quality are: nitrogen dioxide (NO_2), ozone (O_3) and Particulate Matter (PM_{10}).

The health effects of the two key air pollutants in relation to Pluto LNG Development emissions, NO_2 and O_3, are well documented. Nitrogen dioxide irritates the lungs and may lower immunity to respiratory infections. Exposure to high levels of NO_2 causes severe lung injury. Nitrogen dioxide has been demonstrated to increase the effects of exposure to other pollutants such as O_3, SO_2 and small (inhalable) particles. The health effects of exposure to ozone include irritation of eyes and air passages, decreased lung function and development, adverse effects on pulmonary function and aggravation of asthmatic conditions. At high concentrations NO_2 can also cause reduced growth and visible damage in plants.

Occasionally high levels of particulate matter are observed in the Burrup Peninsula region. The health effects of particulate matter relates to the extent to which they can penetrate the respiratory tract. The larger particles with diameters approximately greater than 10 microns are trapped by mucus in the nose, mouth, throat and upper respiratory tract and generally are removed by sneezing and swallowing. Smaller particles with aerodynamic diameters less than 10 microns (PM_{10}) may be inhaled into the lungs. Particles with diameters smaller than 2.5 microns ($PM_{2.5}$) may reach the deepest parts of the respiratory system.

There is limited information available regarding the impacts of atmospheric deposition on Australian flora and vegetation in arid conditions and very little is known regarding air pollution impacts on vegetation occurring on the Burrup Peninsula. In general, studies overseas have found that low levels of NO_2 can be a useful source of nutrient for nitrate dependant plants although if the uptake of NO_2 exceeds the plants' requirements there may be metabolic effects as the plants dispose of surplus nitrogen (Bell and Treshow 2002). A review of the cumulative impacts of nitrogen oxides on the Burrup Peninsula concluded that whilst modelling of nitrogen oxide emissions from existing and proposed industry indicated a potential risk in terms of short term impacts to vegetation, the modelling was not conclusive (EPA 2004c). The review also highlighted the lack of information regarding susceptibility of vegetation on the Burrup Peninsula to air emissions and a lack of knowledge of the interaction and synergistic effect of nitrogen oxides with other air emissions (EPA 2004c).

Studies in the northern hemisphere have found that high levels of O_3 have been found to cause leaf damage to plants, as well as physiological changes and reduction in productivity (Bell and Treshow 2002). However, the effects of ozone on vegetation of the Burrup Peninsula have not been studied and it is difficult to ascertain the ozone levels that have the potential to impact vegetation (EPA 2004c).

The air modelling results (**Section 5.1.2**) indicate that for normal plant operations there will be no exceedences of the relevant air quality criteria for NO_2 and O_3 and that predicted SO_2 and NO_2 depositions on the Burrup Peninsula are within World Health Organisation standards for assessing the risks of impacts on vegetation. The results of the air quality assessment for other atmospheric emissions and pollutants (that is, not associated with combustion products such as NO_x), is that all other pollutants are present at low risk levels in terms of potential air quality impact. This is based on the maximum concentrations predicted for any of these pollutants, for anywhere in the locality, being of the order of (or less than) 1% of their respective ambient air quality criteria, standards and goals. Modelling results for plant upset conditions, including a short-term flaring event of 15 minutes and a flaring event of up to 10 hours during a operations shut-down, indicates that there is a low risk of upset conditions exceeding NEPM standards. In this instance, low risk assumes that exceedences may occur on one or a few hours over an entire year.

Potential air emission impacts on petroglyphs, Aboriginal rock art and engravings are discussed in **Section 11.4**.

Preventative and Management Measures

Management of combustion products from the gas processing plant will be undertaken through implementation of the best available modern LNG processing technologies. The key technologies considered for the proposed Pluto LNG Development designs are:

- dry-low NO_x burners in the process refrigeration and power generation gas turbines and boilers
- Waste Heat Recovery Units to be located on one or more compressor gas turbines improving train efficiency by reducing the consumption of fuel gas
- a Thermal Oxidiser, which is a ceramic bed that oxidises gas streams with small amounts of hydrocarbons without the use of supplemental fuel gas. This represents a decrease in fuel used while destroying more than 98.6% of BTEX in the AGRU vent feed.

The flaring of natural gas (as opposed to venting) reduces the intensity of greenhouse gas emissions and helps to destroy (small amounts of) harmful gas products such as benzene. The flare design specifications will be such that production of CO, NO_x and particulate matter are minimised. Preventative and management measures are summarised in **Table 9-15**.

Management of emissions and discharges expected during commissioning and operation will be further assessed and detailed through the Part V (EP Act) regulatory process in the form of a works approval and operating licence which will require government approval prior to commissioning/operation commencing.

Residual Risk

The residual risk is considered low.

9.5.2 Dark Smoke

Dark smoke can be caused during flaring due to incomplete combustion of products. Environmental impacts from dark smoke emitted from a gas processing plant are considered negligible. The flaring regime at Site A will include a continuous small pilot light at Site A and very occasional flaring under certain circumstances. Flaring at Site B will occur continuously during commissioning (up to approximately six months); however, during operations, flaring will be intermittent and will occur during maintenance, shutdown and during upset conditions.

Dark smoke is expected to be infrequent, particularly during operations, as dark smoke is not expected to be produced when the flare is operating efficiently. The engineering design philosophy for the Pluto LNG Development is to achieve no routine dark smoke emissions.

Preventative and Management Measures

Proposed management measures are summarised in **Table 9-16**.

Residual Risks

The residual risks are considered low.

9.5.3 Dust

Dust emissions are likely to be confined largely to onshore construction-related activities within Development areas. Source activities will include:

- construction traffic transporting materials and workforce to site
- drill and blast activities
- land clearing, earthworks, temporary stockpiling and backfilling
- the operation of a mobile crushing plant.

Wind action over cleared areas and stockpiles is also considered a source of erosion and dust emissions.

Table 9-15 Summary of Impacts, Management and Risks of Combustion Products

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Air pollutants from processing and combustion of natural gas in gas turbines Air pollutants from combustion of natural gas in thermal oxidisers and similar devices Air pollutants from combustion of natural gas by flaring Air pollutants from fugitive emissions of natural gas from the processing plant	Gas turbines for refrigerant compression and power generation Gas combustion units other than gas turbines and flares Marine, wet and dry flares Fugitive emissions	Potential (low risk) ambient air quality impacts primarily from emissions of NO_x reacting with atmospheric gases photochemically and affecting ambient NO_2 and ozone concentrations. Potential (low risk) ambient air quality impacts from pollutants other than those caused by NO_x emissions such as benzene, particulate matter. Potential (low risk) ambient air quality impacts from the components of natural gas.	Flaring events will be minimised to ALARP. Combinations of the following technologies have been implemented in the two plant designs: • Dry-low NO_x burners in the process refrigeration and power generation gas turbines. • Waste Heat Recovery Units (WHRUs) to be located on one or more compressor gas turbines in each train to reduce the consumption of fuel gas. • An AGRU Thermal Oxidiser to destroy sulphurous compounds and hydrocarbons such as BTEX by conversion to CO_2.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Table 9-16 Summary of Impacts, Management and Risks of Dark Smoke

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Dark Smoke	Incomplete combustion during flaring	Reduction of visual amenity	Flaring events will be minimised to ALARP. Maintenance of gas processing plant to ensure efficient flaring Monitor and record the colour and duration of stack emissions: • during a dark smoke event that continues for greater then a 4-minute period during any one hour period • during gas processing plant start-ups and shutdowns • in response to any complaints being received regarding dark smoke • engineering design philosophy will be to achieve no routine dark smoke emissions.	E	3	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Potential Impacts

Dust emissions have the potential to adversely impact the condition of the environment including topsoil, vegetation, fauna and public amenity and may have a temporary impact on local air quality during the construction period. Dust particles in the air can:

- cause visibility difficulties and hence affect site safety
- smother plants and affect the process of photosynthesis
- interfere with and affect respiratory systems.

Dust emissions often vary substantially from day-to-day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. Sensitive dust receptors include:

- the existing Dampier Port area and associated infrastructure <1 km south of Site A
- the NWSV Karratha Gas Plant to the north (<1 km) of Site A

The nearest residential areas are in Dampier, 6 km (straight line distance) south-west of Site A.

Preventative and Management Measures

Proposed management measures are summarised in **Table 9-17**. The management measures proposed will also be effective in mitigating against potential cumulative impacts as a result of dust emitted during site preparation at Site A (Woodside 2006a).

Residual Risks

The residual risks are considered low.

9.5.4 Odour

Potential Impacts

Odour sources are likely to be limited to mercaptans that are typically found as impurities within natural gas (**Section 5.1.5**). Analysed samples of Pluto gas indicate that very little H_2S (that is, below detection limits) and minute quantities of mercaptans are present.

Sensitive receptors within close proximity to the onshore processing plant at Site B include the existing Burrup Fertilisers Ammonia Plant located less than 2 km to the south-east of Site B and the NWSV Karratha Gas Plant, located immediately north of Site B.

Under normal operating conditions there is unlikely to be any odour emanating from the onshore gas processing plant at Site B or the tank storage and export facilities at Site A. Given that Pluto gas contains very little H_2S, has only trace amounts of mercaptans and is not located close to any permanent residential areas, potential impacts are considered negligible.

Preventative and Management Measures

No impacts are envisaged therefore no management measures are required.

Residual Risk

Residual risks from odour emissions are considered low.

9.5.5 Noise

Potential Impacts During Construction

Given that residential sensitive receptors are significant distances away from the main areas of construction, and noise from construction activities will be short-lived, impacts are considered likely but minor.

Table 9-17 Summary of Impacts, Management and Risks of Dust

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Dust	Vehicle movements within and to site Excavation and backfill operations Stockpiling of soil, including excavated material Earthworks	Reduction of visual amenity Smothering of vegetation Loss of topsoil Local air quality deterioration Disturbance to fauna	A Dust Management Plan (**Table G-14**, **Appendix G**) will be developed and implemented and will include the following: • Exposed surfaces such as stockpiles and cleared areas, and the duration that these areas are exposed, will be minimised. • Dust suppression techniques and/or watering of unsealed roads, access routes, exposed ground surfaces and stockpiles will be implemented. • Ensure that vehicles, machinery and loads are properly maintained and covered to minimise dust emissions. A Rehabilitation Management Plan (**Table G-17**, **Appendix G**) will be developed and will include the following principles: • Rehabilitation and stabilisation will be undertaken following completion of the construction activities. A Traffic Management Plan (**Table G-16**, **Appendix G**) will be developed and implemented which will ensure stringent controls on vehicle speeds and restricting travel to designated roads/tracks during construction activities.	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Potential noise impacts from vehicles travelling to the site and from blasting during the construction phase may also occur. Refer to **Section 9.5.6** for impacts from blasting.

Fauna inhabiting the area may be disturbed by construction noise. Short-term displacement of fauna species is likely to occur in and adjacent to the Development area as animals move away from disturbance. However, animals are likely to return to the area once the disturbance has ceased and impacts are therefore considered slight.

Preventative and Management Measures

The prescribed standard, or assigned noise levels, for noise emissions (Regulation 7 of the Environmental Protection (Noise) Regulations 1997) does not apply to noise from construction sites between 7 am and 7 pm provided that the construction work is carried out in accordance with the special case regulation dealing with construction sites (Regulation 13 of the Environmental Protection (Noise) Regulations 1997). In particular, the control-of-noise practices set out in Section 6 of Australian Standard 2436-1981 'Guide to Noise Control on Construction, Maintenance and Demolition Sites' must be adhered to.

A Noise Management Plan (**Table G-6**, **Appendix G**) will be developed and implemented in accordance with Regulation 13 of the Environmental Protection (Noise) Regulations 1997.

A Traffic Management Plan (**Table G-16**, **Appendix G**) will be developed and implemented to control vehicle operations and potential impacts on human receptors.

Potential Impacts During Operation

The predicted noise levels presented previously in **Table 5-15** demonstrate that the assigned noise levels are complied with under all weather conditions considered at residential locations in the town of Dampier. Similarly the aspirational goal of 45 dB(A) for Hearson Cove is complied with under all weather conditions.

However the assigned noise level for the southern boundary of Site B may be exceeded for some meteorological conditions. It should be noted, however, that the model is relatively simple. Each point source in the model represents noise emissions from several equipment items and the model does not include the shielding effects of buildings and other structures at the site. Model predictions at the site boundary are very sensitive to these factors, as well as the precise location of individual items of equipment.

The maximum predicted level of exceedance at the site boundary is 4 dB. This level is likely to alter during the detailed design phase of the Development when more information becomes available on individual items of equipment and the locations of buildings and other structures. Any remaining exceedance should be readily mitigated using localised noise controls or screening of individual items of equipment.

Given the relatively small net increase of traffic expected during the operation phase (with a workforce of up to 150 personnel), potential noise impacts from traffic are considered slight.

The Pluto LNG Development will minimise flaring by optimising the process design and effective maintenance of relief valves and pressure control valves, however, the onshore facilities will have two flare systems:

- Storage and loading flare system at Site A. The flaring regime at Site A will include a continuous small pilot light at Site A and very occasional flaring under certain circumstances including the flaring of boil-off gas to maintain low pressure in the storage tanks. Similarly, occasional flaring of gases within the LNG and condensate tanks may be required prior to ship loading. Flaring events at Site A will be intermittent and short-lived. Noise generally has no residual effect on the environment once the event has ceased and hence has little risk in terms of long-term environmental impact. Potential impacts from flaring at Site A are therefore considered likely but minor.
- Pressure relief and liquid disposal flare system at Site B. The system will include a wet gas flare (wet flare), LNG flare and a common spare flare. At Site B, flaring will occur continuously during the commissioning period for up to six months. Given the continuous and long-lived nature of flaring during commissioning at Site B, impacts are expected to be likely and residual risk is considered high. During operations, flaring will be intermittent and will occur during maintenance, shutdown and during upset conditions. Flaring events during operations will be intermittent and short-lived and potential impacts are therefore considered likely but minor.

Preventative and Management Measures

During front-end engineering and design and detailed design phases of the Development consideration shall be given to noise reduction measures. Measures to be considered include acoustic lagging on compressor suction, discharge and recycle piping. Noise control measures shall be implemented to meet predicted noise levels.

The detailed design of the flare has not been undertaken but it will take into consideration the need to limit noise levels to appropriate standards. The noise levels emitted from this type of flaring will be determined during the detailed design for the flare but will be less than the Woodside absolute standard for noise emissions of 115 dB(A) at the edge of the exclusion area around the flare tower.

Non-emergency flaring will be kept to a minimum and will be infrequent. Automatic control measures will be in place for the detection and control of such releases. These emergency events will be very infrequent (maybe only every five years) and of short duration.

Preventative and management measures are shown in **Table 9-18**.

Residual Risks

Residual risks for construction and operation noise are considered low to high.

Table 9-18 Summary of Impacts, Management and Risks of Noise

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Noise	Construction activities	Impacts on business and industrial properties Disturbance to fauna and residences/ sensitive receptors Impacts on residential areas of Dampier	A Noise Management Plan (**Table G-6**, **Appendix G**) will be developed and implemented to control potential impacts on human and fauna receptors. For construction work outside the hours of 7am to 7pm, and for Sundays and public holidays: • Advise all nearby occupants or other sensitive receptors who are likely to receive noise levels which fail to comply with the standard under Regulation 7, of the work to be done at least 24 hours before it commences. • Submit a Noise Management Plan to the EPA at least seven days before the commencement of construction, with the plan requiring approval by the CEO [EPA].	E	4	L
			A Traffic Management Plan (**Table G-16**, **Appendix G**) will be developed and implemented to control vehicle operations and potential impacts on human receptors.	E	5	L
	Operation of the gas processing plant	Noise impacts from traffic associated with operation workforce	The plant will be designed to <65 dBA along the southern property boundary adjoining (current and potential future) neighbouring industries, and <45 dBA at the Hearson Cove beach shelter. Measures to be considered include acoustic lagging on compressor suction, discharge and recycle piping.	E	5	L
		Noise impacts associated with operations		E	5	L
		Noise impacts from flaring during operation	Detail design will ensure noise levels from flaring are below the Woodside absolute standard for noise emissions of 115 dB(A) at ground level. Flaring events will be minimised to ALARP.	D	5	M
	Commissioning of the gas processing plant	Noise impacts from flaring during commissioning		C	5	H

**C – Consequence; L – Likelihood; RR – Residual Risk*

9.5.6 Vibration

It is difficult to assess in advance the impacts of blasting in terms of airblast overpressure and ground vibration levels. A monitoring and control programme will therefore be implemented to ensure compliance with Regulation 11 of the Environmental Protection (Noise) Regulations 1997.

Allowable overpressure from blasting is detailed in Section 7 of the Environment Protection (Noise) Regulations: 1997. This provides guidance as to the level of overpressure for various time periods.

There is currently no information regarding blast sizes, and it is therefore not possible to predict airblast levels; however, based on the temporary and intermittent nature of the blasting as well as distances to receptors, airblast levels are unlikely to have any significant impact at noise sensitive premises. Predicted impacts therefore considered slight to minor.

Preventative and Management Measures

A Blasting Management Plan (**Table G-7**, **Appendix G**), a Traffic Management Plan (**Table G-16**, **Appendix G**) and a Noise Management Plan (**Table G-6**, **Appendix G**) will be developed and implemented, and will incorporate principles to manage impacts from blasting. Proposed management measures are summarised in **Table 9-19**.

Residual Risks

Blasting and vibration are not anticipated to result in any significant impacts. Residual risk is considered medium.

Table 9-19 Summary of Impacts, Management and Risks of Vibration

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Vibration	Rock blasting	Direct disturbance to fauna.	A Blasting Management Plan (**Table G-7**, **Appendix G**) will be developed and implemented, and will include the following principles: • Fauna activities will be taken into consideration when blasting, especially during sensitive periods for the fauna. • Blasting will be scheduled for daylight hours to avoid impacts during peak activity times (dusk, night, dawn) for nocturnal fauna • Explosives will be used in a manner that will minimise damage or defacement of landscape features and other surrounding objects including the following practices: – increasing the depth of material cover – the use of blankets to minimise upward release of energy and fly rock – optimising charge sizes and spacings to avoid unnecessary energy releases.	D	5	M
		Public access to construction sites and their surrounding areas will be restricted during blasting activities.	A Blasting Management Plan (**Table G-7**, **Appendix G**) will be developed and implemented, and will include the following principles: • Use of sirens and signage to inform construction personnel and members of public that blasting will take place. • Public access to the beach at Site A will be restricted during blasting activities. Warning signs will be placed on the beach, and an observer will monitor the beach from a safe location (either on the beach or a nearby boat) to prevent boats landing or to stop blasting until the beach is cleared. • Local residents near the trunkline corridor will be notified of construction activities in advance.	E	5	L
	Operation of heavy vehicles and machinery during construction.	Disturbance to residences	A Noise Management Plan (**Table G-6**, **Appendix G**) will be developed and implemented.	D	0	L
		Disturbance/ damage to nearby buildings	A Traffic Management Plan (**Table G-16**, **Appendix G**) will be developed and implemented to control vehicle operations and potential impacts on human receptors.	E	2	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Existing Social and Economic Environment

10

10.1 Studies and Surveys

This section of the Draft PER presents a description of the existing social and economic environment within the Pilbara region and in the vicinity of the Pluto LNG Development. A number of studies and surveys have been undertaken to characterise the existing social and economic environment including:

- Archaeological heritage surveys across Sites A, B, D and E by Australian Cultural Heritage Management (ACHM).
- Ethnographic heritage surveys with representatives from the Ngarluma, Yindjibarndi, Wong-Goo-Tt-Oo, Yaburarra and Mardudhunera groups within Sites A, B, D and E with the groups' chosen anthropologist.
- Landscape and visual impact assessment of Site A and Site B undertaken by Sinclair Knight Merz (SKM 2006d).
- An economic assessment undertaken by Allens Consulting and Inside Economics.
- A Social Impact Assessment (SIA) and Management Plan undertaken with input from various academic consultants.

10.2 Social Environment

The objective of this section is to present an overview of the existing social, cultural and economic make-up of the region which is most likely to be affected by the construction, operation and eventual decommissioning of the Pluto LNG Development.

10.2.1 Shire of Roebourne

The proposed Pluto LNG Development will be located on the Burrup Peninsula within the Shire of Roebourne. Towns within the Shire of Roebourne include the coastal towns of Roebourne, Karratha, Dampier, Wickham, Point Samson and the Indigenous community Cheeditha, which all lie within a 50 km^2 radius of each other.

Many Indigenous groups form part of the Shire of Roebourne community and mainly live in the town of Roebourne. Groups directly consulted include the Ngarluma/Yindjibarndi, Yaburarra/Mardudhunera and Wong-Goo-Tt-Oo.

The Shire of Roebourne covers more than 505 000 km^2 and accounts for 20% of Western Australia's total area (PDC 2001).

10.2.2 Population Distribution

The population of the Pilbara region in 2002 was 39 441. The region currently makes up 7.5% of Western Australia's regional population and 2% of the state as a whole. The dominance of the resource industry has impacted on the population dynamics of the region, with periodic influxes of temporary workforces during the construction phases of large projects (PDC 2003). **Table 10-1** provides a summary of population statistics for the area.

In 2005, the population of the Shire of Roebourne increased after a period of decline in the late 1990s. This is mainly due to the resource boom and consequent expansion of resource industries.

Population statistics for the Shire of Roebourne indicate the following characteristics (ABS 2001):

- marginally larger population of males (55%) compared to females (45%)
- the percentage of aged persons has increased from 1996 (4.7%) to 2001 (7.5%)
- relatively small population aged from 15–24 (12.5%), although consistent with regional and state indicators
- large population aged from 25–39 (28.5%).

Table 10-2 summarises the population forecasts for towns within the Shire of Roebourne.

Table 10-1 Population Summary

	Shire of Roebourne	Pilbara	Regional WA	Whole of State
Population (2001)	15 974	39 461	520 818	1 906 114
% Indigenous Population (2001)	11.75%	16.5%	8.4%	3.5%
% Youth (15–24 year olds) (2001)	12.5%	12%	12%	14%
% Aged people (60 year olds+) (2001)	7.5%	8%	16%	15%

Source: Australian Bureau of Statistics (2001)

Table 10-2 Population Forecasts for the Shire of Roebourne

Location	Census 1991	Census 1996	Census 2001	Projected 2006
Karratha	11 325	10 057	10 776	12 756
Dampier	1810	1424	1490	1580
Roebourne	1213	954	946	970
Wickham	1973	1649	1731	1775
Point Samson	180	256	312	360
Balance of Shire	790	610	716	735
Shire Total	**17 291**	**14 954**	**15 974**	**18 176**

Source: Australian Bureau of Statistics (2001); Shire of Roebourne (2006)

10.2.3 Economic Profile and Workforce

The Western Australian economy is currently experiencing boom conditions, driven by strong international demand and associated high prices for the state's commodities (particularly minerals and energy) which has created a favourable investment environment.

The Western Australian economy has been growing at rates around 6% in annual average terms in recent quarters. The recent rapid economic growth has been driven largely by a substantial increase in business investment associated with construction work for a range of major resource-related projects. Employment growth is exceptionally strong, with skills shortages being experienced in many occupations and sectors, affecting all regions in the state.

A large proportion of the business investment has been occurring in the Pilbara region; this is related to major expansions in iron ore mine capacity, as well as the construction of additional LNG trains for the NWSV Karratha Gas Plant. Further expansions are expected, with iron ore and LNG production forecast to double over the course of this decade. As a result, the Pilbara is experiencing exceptional economic growth.

The Indicators for Regional Development Report (DLGRD 2003) provides a useful overview of summary statistics for the whole Pilbara region:

- The gross regional product per capita of $114 625 is much higher than the regional average ($50 301) and Perth ($34 593).
- Prices for goods are 11.3% higher than in Perth and median housing prices are higher compared with regional Western Australia.
- A lower than average unemployment rate (4.3%) compared with the regional average (6.2%) and that of Perth (6.6%), although Indigenous unemployment is higher.

Considerable employment opportunities have arisen within the Shire of Roebourne due to resource development. The highest employment industry within the Shire of Roebourne is mining, employing 18% of residents. The construction industry provided 12% of residents with employment. Other significant industries include retail, government and manufacturing (ABS 2001).

Figures drawn from the Australian Bureau of Statistics show that although 68% of non-Indigenous incomes were above $25 968 in 2001, 78% of Indigenous incomes were well below this figure. The unemployment rate for Indigenous groups was 18.3% in 2001 according to the Australian Bureau of Statistics, with the non-Indigenous unemployment at 4.8%.

10.2.4 Housing and Accommodation

The demand for accommodation and housing in the Shire of Roebourne is directly linked with new development and operation of resource companies within the area. The majority of people residing in the Shire of Roebourne are involved with resource companies or industries servicing these companies and government agencies (local and state).

The key issues surrounding the accommodation and housing market include:

- rental price fluctuations and availability over the past 18-months (increase $150 per week)
- ballooning sales market, much higher than median house prices in Perth
- demand for residential land in Karratha to meet the increase in rental and owner-occupier accommodation
- transient construction workforce, which results in population increases/decreases.

Rental Market

The demand for rental properties and rental costs in the town of Karratha fluctuates greatly with resource development and expansion (**Table 10-3**).

The rental cost of the average four bedroom family home in Karratha increased by 16% between March 2004 and December 2005, with availability decreasing by 43%.

There is also a significant stock of company-owned accommodation and government accommodation. Government housing comprises Homewest and Government Employee Housing Association (GEHA) tenants of which Homeswest had 430 tenants and GEHA had 439 tenants for the December 2005 quarter. Pilbara Iron had 166 employees in company-owned accommodation with the remainder of their housing stock on the private rental market. Woodside had 448 properties occupied for the December 2005 quarter (PDC 2005c).

Other options for rental accommodation or temporary accommodation are in the form of caravan parks and holiday parks. Karratha has three caravan parks, and there is also one in Roebourne, one in Point Samson and a transit park in Dampier. The three parks in Karratha have a total of 455 sites with the other parks mainly catering for tourists (**Table 10-4**).

Sales Market – Private Ownership

Median housing prices in Karratha have increased during the last five years by 98.5%. Price increases were recorded in all types of housing in the March 2006 quarter with the following increases recorded:

- two bedroom increase by 16.2% - price range $251 000 to $300 000
- three bedroom increase by 1.5% - price range $350 000+
- four bedroom increase by 1.5% - price range $501 000+.

Over the same quarter there was a 111% increase in the number of properties advertised for sale (PDC 2006).

Land Availability

Demand for land in Karratha has risen dramatically to meet the growing demand for owner-occupier and rental accommodation.

LandCorp has completed all site works within the Tambrey Development which consists of 176 residential blocks located adjacent to the Tambrey Function Centre. All resitential blocks within the Tambrey Development have been sold, the blocks range in size from 540–835 m^2.

Site works have commenced on the Nickol West Development, with the first release of residential blocks due in the first quarter of 2007. It is anticipated that 150 blocks will be released. The Nickol West Development is located on Balmoral Road, alongside Bay Village and adjacent to the Tambrey Primary School.

LandCorp and the Shire of Roebourne have commenced planning for further land developments in Baynton with approximately 800 blocks and public open space being included in the design.

Construction Workforce Accommodation

Table 10-5 provides details of committed projects, and the projects that may proceed in the Karratha area over the next three years. These projects will all require construction workforce accommodation.

The NWSV has one construction village in Karratha and a private company owns another camp located on Searipple Road. Construction workforce accommodation is also available in Dampier. Availability of accommodation at these camps is very much dependant on the progress of the above projects.

Table 10-3 Rental Summary for Karratha

	Number of Advertised Rentals				Average Advertised Cost/Week			
	Mar 04	Sept 05	Dec 05	Mar 06	Mar 04	Sept 05	Dec 05	Mar 06
1 Bed	5	1	8	11	$393	$261	$252	$332
2 Bed	5	2	2	6	$393	$261	$252	$332
3 Bed	20	0	18	25	$410	$496	$501	$554
4 Bed	23	0	10	9	$623	$703	$723	$675

Source: Pilbara Development Commission (2006)

Table 10-4 Capacity and Availability of Karratha Caravan Parks

	Number of Sites			Number of Vacancies			Average Price/ Week		
	Mar 04	Dec 05	Mar 06	Mar 04	Dec 05	Mar 06	Mar 04	Sept 05	Dec 05
Onsite vans	68	110	67	5	35	8	$190	$219	$210
Cabins	10	10	10	3	2	2	$465	$209	$1100
Powered sites	324	405	340	166	126	193	$110	$150	$175
Ensuite facilities	64	3	78	3	0	6	$161	$175	$210
Motel/chalet	6	14	24	4	12	17	$546	$550	$749

Source: Pilbara Development Commission (2006

10.2.5 Community Services and Infrastructure

Key services and infrastructure likely to be affected by shifts in population are education, health, community and recreation facilities and emergency services. **Table 10-6** lists available services in each town.

Table 10-5 Committed and Potential Future Projects in the Karratha Area

Project	Approx Construction Workforce	Impact on Karratha	Approx Permanent Workforce	Estimated Construction Start/ End Date
North West Shelf – Train 5	1500 peak Q3/07	1500	20	Quarter 3, 2005 to Quarter 4 2008
Hope Downs Iron Ore Project	600	-	-	Quarter 1 2006 to Quarter 3 2008
Pilbara Iron – Upgrade	505 peak Q3/04	600	0	Quarter 4, 2003 to Quarter 4, 2007
Mineralogy	-	-	-	Quarter 4, 2006
Dampier Nitrogen	1000	1000	130	To be assessed
Gorgon – Barrow Island	2200 on Barrow	30	10	Quarter 3, 2006 to Quarter 2, 2010
West Kimberley Power Project	50	50	10–12	Quarter 1, 2006
Woodside – Pluto LNG Development	2700peak 2009	2700	>150	Quarter 4. 2006 to Quarter 4, 2010

Source: Pilbara Development Commission (2006)

Table 10-6 Key Available Services and Infrastructure

Services	Karratha	Dampier	Roebourne	Wickham	Point Samson
Primary schools	✓	✓	✓	✓	
Secondary schools	✓				
Child care services	✓	✓	✓	✓	
Community centre	✓	✓	✓	✓	✓
Library	✓	✓	✓	✓	
Churches	✓	✓	✓	✓	
Recreational centre	✓				
Shopping centre	✓	✓		✓	
Post office	✓	✓	✓	✓	
Hospital	✓		✓		
Medical centre	✓	✓	✓	✓	
Light industrial area	✓		✓	✓	
Post secondary education facilities	✓		✓		
Police station	✓	✓	✓	✓	
Regional court and facilities	✓		✓		
Emergency services	✓	✓	✓	✓	
Tourist accommodation	✓	✓	✓		✓

Education

The provision of public education within the Shire of Roebourne is managed by the Education Department of WA, which has a regional office in Karratha.

Karratha has four public primary schools: Millars Well, Karratha Primary, Pegs Creek and Tambrey, and one private Catholic primary school, St Paul's. Dampier, Wickham and Roebourne also have one government-funded primary school each. Nearly 1500 children attend these primary schools (Shire of Roebourne 2006).

Secondary schooling is offered in Karratha and Roebourne. Karratha Senior High School and St Luke's (a private Catholic Secondary College) cater for students from Years 8 to 12. Karratha Senior High School has capacity for 600 students and St Luke's capacity is 210 students (Shire of Roebourne 2006). Students in Roebourne and Wickham can attend Years 8 to 11 at the Roebourne Annex of the Karratha Senior High School, after which students must travel to Karratha for Year 12.

Through Pilbara TAFE, Curtin University and Karratha Senior High School are working together to provide school leavers with access to a range of technical courses and undergraduate and postgraduate degree programmes. The TAFE also offers training and education to mature age students and resource companies.

Emergency Services

Emergency services within the Shire of Roebourne are largely reliant on volunteers, with the exception of the WA Police Service. Emergency services in Karratha include St John's Ambulance, the State Emergency Services, Fire and Emergency Services (FESA), Police Service and Sea Search and Rescue.

A contingency plan for Karratha was developed four years ago by the Shire of Roebourne and FESA to plan for any situation where demand exceeded the service available. Major resource operations such as the NWSV and Pilbara Iron have their own dedicated emergency response teams.

Training and skills development for emergency services personnel in the region is limited and the majority of training is conducted in Perth. St John's Ambulance has a Karratha-based training programme that includes First Aid courses and programmes specialised for resource companies.

Recreation, Leisure and Community Facilities

The Shire of Roebourne is well supplied with recreation and community facilities when compared to local government authorities in the metropolitan area. However, a majority of this infrastructure is ageing and in need of upgrading. Support to local sporting and community groups is mainly funded through the Shire of Roebourne Grants Scheme or the Department of Sport and Recreation which has a regional office in Karratha.

As the major population centre within the Shire of Roebourne, Karratha has an established range of recreation and community facilities, which include:

- Karratha Aquatic Centre (50 m, 25 m and children's pool)
- Karratha Entertainment Centre (indoor court and gymnasium)
- four public reserves (two fully lit to Australian Standards)
- tennis and netball complex (outdoor, fully lit)
- Karratha Country Club (lawn bowls and 18-hole golf course).

Wickham, Dampier and Roebourne are serviced by smaller facilities, and once again are generally around 20 years old and in need of continual maintenance. As part of the Roebourne Enhancement Scheme, construction is currently underway to develop covered basketball courts near the Roebourne Primary School. Facilities in Dampier and Wickham are maintained by Pilbara Iron.

The Shire of Roebourne has adopted a strategic plan for sport, recreation and leisure which assessed user satisfaction levels and service provision. Seventy to eighty percent of the respondents reported highest levels of satisfaction in taking part in recreational activities of fishing, movies, the library and public reserves. The highest level of dissatisfaction was recorded regarding children's playgrounds, beaches and boat ramps.

Medical and Health Services

Karratha and Roebourne are the only towns within the Shire of Roebourne that are serviced by district hospitals, namely the Nickol Bay District Hospital and Roebourne District Hospital. There is also a regional hospital in Port Hedland that provides specialised medical care to residents across the Pilbara.

Nickol Bay Hospital is a modern well-equipped hospital with the ability to manage most emergency health care needs. The hospital has doctors working on a full-time roster and an on-call basis who provide anti-natal, anaesthetic and surgical services. Medical specialists periodically visit the hospital to provide further medical services to the community.

The West Pilbara Health Service operates and manages the Nickol Bay Hospital and also provides community and child health services, drug and alcohol counselling, mental and disability services and sexual and domestic violence counselling. Community and child health services are also available in Roebourne and Wickham. Physiotherapy and X-ray services are catered for by private practitioners and as well as by West Pilbara Health Service.

As with many regional areas, there are challenges in attracting and retaining adequate general practice medical services to the Pilbara. Ability to access general practitioners in the Shire of Roebourne has been somewhat relieved with Karratha Medical Centre now offering same day appointments and opening seven days a week. Medical centres are also located in Dampier, Wickham and Roebourne.

10.3 Aboriginal Heritage

Burrup Industrial Estate

Consistent with the land use framework described in the Burrup Land Use Management Plan, developed over a decade ago, in January 2000, the Western Australian Government notified its intention to acquire land on the Burrup Peninsula and adjacent Maitland area for the construction of heavy industrial estates. At the time, there were three registered Native Title claims covering the proposed acquisition area, the Ngaluma / Injibarndi, Yaburara / Mardudhunera and the Wong-Goo-To-Oo people.

As a result of negotiations between the Western Australian Government and the Native Title claimants, in January 2003 the Burrup and Maitland Industrial Estates Agreement (BAMIEA) was signed. Under this Agreement, the claimants accepted a number of benefits in exchange for the extinguishment of Native Title on the Burrup and Maitland Estates industrial land, the establishment of an industrial estate and the setting aside of land required for residential and commercial purposes in Karratha.

10.3.1 Statutory and Regulatory Framework

Aboriginal heritage sites in Western Australia are managed under the *Aboriginal Heritage Act 1972* (WA) (Aboriginal Heritage Act) which is administered by the Department of Indigenous Affairs (DIA). Woodside has submitted detailed information pertaining to management of Aboriginal heritage for the Pluto LNG Development to the DIA.

Aboriginal heritage is also considered under the EP Act through the environmental impact assessment process administered by the EPA. Aboriginal heritage is considered under the EP Act only in circumstances where it constitutes a relevant environmental factor.

The EPA considers Aboriginal heritage as a relevant environmental factor in circumstances where heritage values are linked directly to the physical and biological attributes of the environment, and when the protection and management of those attributes are threatened as a result of a proposed development (EPA 2004b).

Given the potential for overlap between the Aboriginal Heritage Act and EP Act, the EPA has issued a Guidance Statement on assessment and management of Aboriginal heritage (EPA 2004b). The Guidance Statement seeks to ensure that proponents comply with the Aboriginal Heritage Act and EP Act, and details the following actions pertinent to Aboriginal heritage:

- Consult with staff of the DIA and review site records (desk-top review) in accordance with the Aboriginal Heritage Act.
- Undertake an Aboriginal heritage survey (if it is noted from a desk-top review that an adequate survey has not been undertaken for an area to be developed) which should include consultation with appropriate Aboriginal people, and may include an anthropological survey, and if necessary, an archaeological survey.
- Inform and consult the relevant Aboriginal people about details of the proposed development, including potential environmental impacts.
- Demonstrate that any concerns raised by Aboriginal people have been adequately considered by the proponent in its management of environmental impacts, and any changes as a result of this process are made known to Aboriginal people.

10.3.2 Regional Setting

The Western Pilbara Region and associated islands contain a prolific and diverse range of Aboriginal heritage sites (archaeological and ethnographic). The types of heritage sites occurring in the region include, but are not limited to, shell middens, standing stones, stone features (for example, hunting hides and pits), grinding patches, quarries, rock art and artefact workshops. Such heritage sites date Aboriginal occupation in the region to many thousands of years ago.

Rock art (often referred to as petroglyphs, rock engravings or carvings) is the most distinctive archaeological site type in the region. Rock art sites in the western Pilbara are prolific and stylistically variable (for example, Maynard 1977; McCarthy 1961; 1962; Wright 1968). There are approximately a dozen significant localities for rock art in the region, including the Yule River sites (Woodstock, Abydos), Cooya Pooya and the Fortescue River, Port Hedland, Depuch Island, and the Dampier Archipelago (Vinnicombe 2002). These areas contain large galleries of petroglyphs, with many local variations in style and subject, as well as some common characteristics across the region and beyond (Vinnicombe 2002).

It has been estimated that the Dampier Archipelago may contain over a million pieces of rock art, with a recorded range from 17 to 77 Aboriginal heritage sites per square kilometre based on heritage survey data from the Burrup Peninsula and nearby islands (Vinnicombe 2002). At least half of the heritage sites on the Burrup Peninsula are expected to be rock art, with the remainder comprising other types of sites such as middens, standing stones and artefact workshops. However, these are only estimates, as much of the Burrup Peninsula and surrounding islands have not been surveyed, and the quality and accuracy of information recorded in the DIA Register of Aboriginal Sites over the last 30 years is highly variable. At present, more than 2000 Aboriginal heritage sites are listed by the DIA Register of Aboriginal Sites on the Burrup Peninsula. The archaeological and ethnographic heritage landscape identified during the heritage surveys of Sites A, B, D and E illustrate the long associations between the Burrup Peninsula and the Indigenous people over possibly thousands of years.

Site A and Site B, the proposed location of the LNG jetty, tanks and gas processing plant, have been zoned industrial and reserved for industrial use with the agreement of the Indigenous groups under the Burrup and Maitland Estates Industrial Agreement. This agreement was signed between the state of Western Australia and the Indigenous groups of the area in 2003.

10.3.3 Pluto LNG Development Area

Woodside has conducted desktop research and detailed archaeological and ethnographic heritage surveys to understand the heritage environment on its leases. This approach has provided Woodside with a very detailed understanding of the heritage environment at Site B and Site A that is documented in the following section. **Section 11** of the Draft PER summarises the impact that the Pluto LNG Development will have on the heritage landscape.

Desktop Surveys

Prior to conducting heritage surveys for the Pluto LNG Development, Aboriginal heritage was a consideration in Woodside's site selection study (**Section 3.2.1**). In relation to the Burrup Peninsula, Woodside (through knowledge of the outcomes of previous Aboriginal heritage surveys) was of the understanding that rock art is generally located in deep valleys and on large rocky outcrops. With this in mind, and coupled with the technical difficulty of locating large infrastructure within valley areas, Woodside has chosen to develop the gas processing plant and associated infrastructure on sites that contain large, flat, plateau-style upland areas. For example, the storage tanks within Site A will be located outside the valley systems present in the southern portion of Site A. The infrastructure proposed for Site B, with the exception of the crossing points required over gullies, will be located on the comparatively flat areas that lie between the gullies. As discussed in **Section 11** of this Draft PER, Woodside's consultation with relevant parties and its decision to locate infrastructure on these relatively flat areas will result in an estimated 95% of the rock art on Site A and Site B being left undisturbed and in-situ. Woodside intends to relocate the remaining 5%.

Background and desktop research was conducted by anthropologists, archaeologists and Geographic Information Systems (GIS) analysts. Previous heritage survey reports, relevant files from the Register of Aboriginal Sites, and GIS spatial data for Aboriginal sites were found and accessed using DIA databases.

The desktop review showed only partial coverage of Site A and Site B by previous heritage surveys. Previous studies for Site A included:

- WA Museum Reconnaissance Survey 1979
- Dampier Archaeological Survey 1980–1981, covering approximately 15% of the Burrup Peninsula, conducted by the Department of Aboriginal Sites of the WA Museum
- King Bay/Hearson Cove Survey in 1996 commissioned by the Department of Resources Development (now the Department of Industry and Resources) and conducted by Dr Patricia Vinnicombe (Vinnicombe 1997). The survey was conducted in the area between King Bay in the west and Hearson Cove in the east. The survey was necessitated by the drafting of the Burrup Peninsula Land Use Plan and Management Strategy
- Woodside Lease Extension Area Survey 1997
- Burrup West Service Corridor Survey 1999
- Survey of proposed construction and infrastructure service corridors between the Dampier Port and the proposed Hearson Cove industrial sites on the Burrup Peninsula in 2003, conducted by Australian Cultural Heritage Management (ACHM).

Site B has been partially surveyed and previous studies included:

- Dampier Archaeological Survey in 1980–1981, covering approximately 15% of the Burrup Peninsula, conducted by the Department of Aboriginal Sites of the WA Museum
- Survey of the proposed north-south infrastructure corridor in 2003, conducted by ACHM
- Survey of the southern part of Site B for the previously proposed Agrium Development in 2005 by John Clarke and Joe Mattner.

The results of the desktop studies were used to produce a series of maps depicting locations and extent of known sites. These maps were used in the field by Indigenous groups, anthropologists and archaeologists to conduct heritage surveys.

Field Surveys

Detailed archaeological field surveys were undertaken to verify locations of previously recorded sites and locate and assess the significance of previously unrecorded sites. Information for previously recorded sites was also updated.

Archaeological heritage surveys have been completed over Sites A, B, D and E by Australian Cultural Heritage Management (ACHM). The Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera groups completed ethnographic heritage surveys together and the Wong-Goo-Tt-Oo group completed their ethnographic heritage survey separately. In effect, the Pluto lease areas were surveyed for heritage sites three times, each with a separate group of people.

At Site A and Site B, where the LNG jetty, storage tanks and gas processing plant will be located, the survey methodology involved walking over the land in contiguous parallel transects in topographically distinct segments. Transects varied in spacing from 5 to 20 m, depending on terrain and surface visibility. This included close examination of the base and top of rock outcrops by circumnavigation and longitudinal inspections. Tops and slopes of the larger outcrops were circled and zigzagged as necessary to inspect all rock faces.

Because of changing conditions of light and shade, and the dominance of rocky boulder slopes and outcrops on the landscape, 100% site discovery is never a certainty on the Burrup Peninsula. However, the ground coverage achieved by the site inspection is comprehensive by industry standards, and 95% accountability of all archaeological sites is estimated in the most prolific rock art areas (for example, at Site A).

Ethnographic Surveys

Two ethnographic heritage surveys were conducted over Site A and Site B: one with representatives from the Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera groups and the other with the Wong-Goo-Tt-Oo group.

The Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera groups conducted their ethnographic heritage surveys with Australian Interaction Consultants as their chosen anthropologist. The Wong-Goo-Tt-Oo group conducted ethnographic heritage surveys with R and E O'Connor Pty Ltd as their chosen anthropologist.

The survey methodology included the following:

- desktop and database search
- field surveys using pedestrian transects – the location, descriptions and characteristics of ethnographic features were recorded during these surveys
- post-survey meetings with representatives of the Aboriginal groups to present survey results and discuss how Woodside could best minimise its impacts to the heritage environment.

Assessment of Significance

Archaeological sites identified during the surveys of Site A and Site B were assigned an archival, low, medium or high archaeological significance rating. The rating was based upon a range of relevant significance assessment criteria, standards and methodologies. These included the following:

- research value and representativeness as defined by Bowdler (1981; 1984)
- cultural significance, as defined by Australia ICOMOS Burra Charter (1999)
- Australian Heritage Commission criteria, under the *Australian Heritage Commission Act 1975* (Cwth)
- national heritage significance criteria under the EPBC Act
- rock art significance assessment.

The significance levels are defined in **Table 10-7**.

Ethnographic heritage sites were also given a significance rating by the anthropologists based upon their consultation with the Aboriginal groups that participated in the surveys. The Aboriginal groups of the area assign a high significance rating to the Burrup Peninsula.

Site A Heritage Environment

During the archaeological survey a total of 80 archaeological sites were recorded at Site A, including 47 previously unrecorded sites and 33 previously recorded sites. The survey found that these sites include a total of 1240 rock art panels and 2488 individual motifs. The majority of sites are distributed along the eastern and south-western margins of Site A associated with rocky hills, intervening valleys and watercourses, and will not be impacted by the Development. **Table 10-8** presents the types and numbers of archaeological sites within Site A, as identified during the archaeological heritage survey. Development at Site A will occur over 15 to 20 ha in the northern portion of the site where heritage sites occur in lower densities and are mostly of lower significance than in other areas of Site A. Woodside will liaise with the Indigenous groups of the area and other experts to ensure no disturbance occurs in the southern portion of Site A.

The Site A ethnographic heritage surveys found large site complexes in the southern area of Site A and on the eastern margin of the site. The beach area at Site A was also considered to be highly significant.

Table 10-7 Archaeological Significance Ratings

Rating	Description
Archival	Includes sites that no longer physically exist and have significance only as archival information.
None	Places that have been previously recorded as archaeological sites but which have been assessed to be of natural origin and not modified by past Aboriginal activities.
Low	Minimally altered places such as low-density artefact scatters or single/small groups of engravings of small size and simple composition, grinding patches or other Aboriginal site features which contain little information and/or are a common class of site.
Medium	Sites that are relatively common and tend to have only moderate differentiation in information potential and character among them, and that have a good potential for recording and information recovery, (such as medium density artefact scatters, quarry/workshops, and open camp sites), or which have good potential for recording and relocation without significant loss of information (for example, a single engraving, or small groups of engraving boulders that are only moderately well preserved and/or capable of salvage and relocation).
High	Sites of a class that is considered to be rare or a site which has rare or unique research or educational qualities, sites which have a high/varied research and/or educational potential, including major archaeological deposits, quarry/workshops, most engraving sites – particularly larger and more varied sites that are well preserved.

Table 10-8 Archaeological Sites within Site A

Type of Archaeological Site	Number Recorded Within Site A
Artefacts	4
Artefacts/Structure (for example, stone hunting hide)	1
Engraving (petroglyphs)	66
Engraving/Artefacts	1
Engraving/Artefacts/Grinding Patch	1
Engraving/Midden/Artefacts	1
Engraving/Structure	1
Engraving/Quarry	2
Structure	3
Total	80

Site B Heritage Environment

A total of 107 previously unrecorded archaeological sites were recorded during the archaeological survey of Site B in June 2006. In addition to these, eight sites previously recorded by DIA were verified as being located within Site B. Fourteen other archaeological heritage sites, recorded by a previous Site B proponent, were also verified as being located within Site B. In total, the archaeological heritage survey identified a total of 129 archaeological heritage sites within Site B, of which 105 have rock art components that total an estimated 220 rock art panels (rock faces with one or more rock art engravings) that comprise 356 individual rock art engravings (motifs) **Table 10.9**. Site B is approximately twice the size of Site A but has a relatively sparse distribution of rock art in comparison. For example, based on the archaeological heritage survey results, Site B has less than one fifth of the rock art of Site A.

At the time of writing this Draft PER Woodside was not in receipt of the Wong-Goo-Tt-Oo's survey report so is unable to document the key findings of that survey. The Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera group ethnographic survey resulted in the identification of two large and highly significant ethnographic site complexes that span the margins of Site B and in particular the southern and central valley systems.

Table 10-9 Archaeological Sites within Site B

Type of Archaeological Site	Number Recorded within Site B
Artefacts	9
Artefacts/ Engraving	11
Artefacts/ Engraving/Structure	1
Artefacts/Midden	1
Engraving	89
Engraving/Artefacts/Grinding Patch	1
Engraving/Grinding Patch	1
Quarry/Artefacts	3
Quarry/Artefacts/Engraving	2
Structure	11
Total	129

While in a local context the numbers of heritage sites within Site A and Site B may seem large, in a regional context these numbers are very small. For example, it has been estimated that there may be over one million pieces of rock art within the Dampier Archipelago, only a fraction of one percent of this rock art lies within Site A and Site B and an even smaller percentage of rock art lies within the proposed disturbance footprint. **Section 11** of this Draft PER outlines the impact that the Pluto LNG Development will have on the heritage landscape.

Consistent with the land use framework described in the Burrup Land Use Management Plan, developed over a decade ago, in January 2000, the Western Australian Government notified its intention to acquire land on the Burrup Peninsula and adjacent Maitland area for the construction of heavy industrial estates. At the time, there were three registered Native Title claims covering the proposed acquisition area, the Ngaluma / Injibarndi / Mardudhunera and the Wong-Goo-To-Oo people.

As a result of negotiations between the Western Australian Government and the Native Title claimants, in January 2003 the Burrup and Maitland Industrial Estates Agreement (BAMIEA) was signed. Under this Agreement, the claimants accepted a number of benefits in exchange for the extinguishment of Native Title on the Burrup and Maitland Estates industrial land, the establishment of an industrial estate and the setting aside of land required for residential and commercial purposes in Karratha. The benefits contained in the Agreement were intended to endure regardless of whether the Native Title claims over the area were upheld by the Federal Court.

Benefits to the Native Title claimants included:

- conditional freehold title to Burrup Peninsula non-industrial land
- allocation of developed land allotments in Karratha
- financial compensation
- provisions for employment, education and training
- a rock art study to monitor impacts of emissions
- a Shire enhancement scheme
- protocols for Aboriginal heritage surveys of the area.

In July 2003, six months after the signing of BAMIEA, the Federal Court found that Native Title no longer existed over the Burrup Peninsula.

Land use under BAMIEA is managed under the Burrup Land Use Management Plan. The areas on the Burrup Peninsula that are considered in this Draft PER lie within the industrial lease areas identified under the management plan or within existing industrial leases.

National Heritage Listing

The rock art of the Dampier Archipelago, including the Burrup Peninsula, islands of the Dampier Archipelago and the Dampier coast are currently being assessed for inclusion on the National Heritage List. The areas are currently listed as 'nominated places' for protection under the EPBC Act. Two areas that are specifically included are:

- Site 105727 Burrup Peninsula, Islands of the Dampier Archipelago and Dampier Coast (42 300 ha)
- Site 105711 Dampier Archipelago Art Site Area, Karratha (114 000 ha).

In September 2006, the Australian Heritage Council recommended in their assessment that areas within the Dampier Archipelago be placed on the National Heritage List. The Commonwealth Minister for Environment and Heritage, Senator Ian Campbell, has said that he does not have a view on whether the area should be placed on the National Heritage List and has sought further public comment by 28 November 2006. The Minister is expected to make a decision regarding heritage listing in late 2006 or early 2007.

Aboriginal Rock Art

The Burrup Peninsula has the greatest abundance and highest concentration of rock art that is known in the world (DEC 2006). The images were created in the Pleistocene era and are estimated to be at least 10 000 years old. Rock art exists throughout the Burrup Peninsula. Some images are readily seen from roads and tracks, beaches and picnic spots; others are in isolated, inaccessible areas and hidden from view (DEC 2006). The art depicts a range of human and animal figures and other non-representational (for example, schematic) designs.

The rock art of the Burrup Peninsula is in the form of petroglyphs. Petroglyphs are images that have been carved, pecked or scraped into a rock surface (DEC 2006). The four main techniques employed on the Burrup Peninsula as described by Vinnicombe (2002) are scoring, pecking, abrasion and pounding. Scored lines are made by dragging a sharp point across the rock face. Hitting the rock surface with a fine pointed implement creates peck marks ranging from fine to coarse and from circular to angular. Abraded lines and indents are made by repeatedly rubbing a hard object backwards and forwards on the rock surface. Images that show no perceptible depth appear to have been made simply by bruising the rock with a pounding action. A petroglyph may have been created using a single technique or the combination of two or more of the above.

The Burrup Peninsula petroglyphs are found on the weathered rock surfaces of granophyric rhyodacite, granites, gneissic granites and gabbro; these are igneous rocks, which are formed when molten magma cools. The granites and gabbro of the Burrup Peninsula are coarse-grained, while the granophyre is a fine-grained rock. Most of the petroglyphs are found on granophyric rhyodacite (Vinnicombe 2002). The settings for the petroglyphs can take many forms: a single motif in isolation on the top of a rocky hill (for example, a lizard or turtle); boulder strewn rock outcrops with perhaps a dozen or more petroglyphs; steep-sided rocky valleys with rock pools containing hundreds and sometimes thousands of petroglyphs adorning the boulders and valley walls. In many places there is a group of petroglyphs with similar motifs. For example, clusters of petroglyphs on rocky headlands on the coast in some places depict a range of sea creatures such as turtles, stingrays, whales and crustaceans.

The granophyric rhyodacite of the Burrup Peninsula is typically blue-grey rock with a surface coating that is weathered to a deep reddish-brown. This surface coating is known as a patina or rock varnish. Rock varnish is generally comprised of clay minerals and hydroxides, or oxides of either manganese or iron; approximately 70% of the varnish is clay and approximately 30% is manganese or iron hydroxides/oxides although trace amounts of other elements/minerals may be present (Perry et al 2003; Dorn 2004a; Bhatnagar and Bhatnagar 2005). Rock varnish varies in colour from orange to black depending on the different concentration of manganese (black) and iron (red) oxides (Bhatnagar and Bhatnagar 2005). It is not completely understood how the rock varnish forms. Theories have included biological, geochemical or a combination of both processes (Bhatnagar and Bhatnagar 2005). There is substantial evidence that microbes are associated with rock varnishes (Perry et al 2003); however, the microbes and organic chemicals found do not explain how the rock varnish is formed. It is thought that rock varnish may be created by a four-step process (Dorn 2004a). Firstly, the varnish is enhanced by bacteria, then there is chemical dissolution of bacterial sheaths where the manganese and iron are broken down into granules (Dorn 2004a). The third step is chemical transport of manganese and iron into clay mineral and lastly precipitation of manganese and iron inside the clay minerals (Dorn 2004a). Other processes that may form the rock varnish are the recombination of aerosol particulates after accretion to the rock surface or precipitation of wet aerosols or soluble components in rain/dew; both these processes allow for microbial facilitation (Lau et al 2005).

Rock varnish in other areas of the world is often glossy, for example, the glossy black rock varnish on rocks in California (Dorn 2004b). However, the rock varnish on the Burrup Peninsula varies from light-red to dark brown-red and is usually matt (Lau et al 2005). Preliminary studies of the rock varnish on the Burrup Peninsula suggest that the surface coating is clearly different in morphology and composition to the interior bulk rock (Lau et al 2005). Samples taken from the Burrup Peninsula show the rock varnish to be approximately 20 to 200μm thick (Lau et al 2005).

Some petroglyphs are clearly visible due to a colour contrast between the red-brown rock varnish and cream-white colouration of engraved lines whilst others exhibit no colour contrast at all (Vinnicombe 2002). Factors that determine the degree of colour contrast are the thickness of the rock varnish, the depth to which the image penetrates into the rock, and the length of time that has elapsed for the image to become weathered (Vinnicombe 2002).

10.4 European Heritage

The European heritage, settlement and establishment of Karratha and Dampier are documented in several studies. The following section summarises information provided by the WAPC (1998) and the PDC (1995).

From as early as 1618, European ships were sighted off the Pilbara coastline, and in 1689 William Dampier, the first known European explorer to make contact with the Karratha area, sailed his ship 'the Roebuck' to the region and anchored in the Dampier Archipelago Islands. Some ten years previously he had explored the region on the 'Cygnet' and had reported the area as having an inhospitable coastline and a lack of water.

The explorers Baudin and King followed later, with Lieutenant Phillip Parker King surveying the local coastal areas in 1818 and 1822 and naming Nickol Bay. In 1861, FT Gregory undertook the first land-based expedition travelling from Hearson Cove to the Hamersley Ranges and Millstream. Gregory reported the abundance of iron ore in the Pilbara, named the Fortescue and Ashburton Rivers, and made a recommendation for the use of the land for pastoral purposes.

The Pilbara region was first settled by Walter Padbury near Cossack on the mouth of the Harding River, in May 1863. John Withnell soon followed and the development of a small settlement provided the impetus for the establishment of the town of Roebourne in 1866.

Cossack developed as a port for Roebourne and supported the pearling industry, and from 1870 to 1872 a whaling station was established on Malus Island; however, some years later, in 1884, the pearling industry was relocated to Broome.

The pastoral industry continued to grow during the late 1800s and the associated growth of the wool industry resulted in the establishment of Onslow, Point Samson and Port Hedland. Pastoralism dominated the Pilbara up until the early 1960s when a downturn resulted from drought, flood, fluctuation of market prices and the introduction of more efficient transport systems. Coinciding with this were the local discoveries of iron ore, natural gas and petroleum offshore and more recently solar salt production. The resource boom that followed led to the establishment of new settlements, construction of railways, airports, harbours and further ongoing development.

Buildings and places of heritage value are those that have a defined connection to the early European settlement and development of Karratha and its surrounds, and include historic homesteads and buildings, old pastoral stockyards, grave sites, remains of early industry operations, shipwrecks, campsites, beaches, waterways, islands, vegetation, hills and valleys and the wildlife they support. The Register of the National Estate and the Register of the Heritage Council WA list places of historical, Indigenous and natural significance. **Table 10-10** contains a list of historical places on the registers. Indigenous and natural places on the registers are described in **Section 10.3** and **Section 10.6** respectively.

Table 10-10 Registered Places (Historical) in the Karratha, Dampier and Burrup Areas

Place Name	ID Number	Location
Register of the National Estate		
Karratha Station Group	010114	Karratha WA
Grave Site on Dolphin Island	010104	Dampier, WA
Legendre Island Lighthouse	019843	Dampier, WA
Malus Island Whaling Site	010105	Dampier, WA
Pearling Relics Black Hawke Bay	010108	Dampier, WA
Tryall Shipwreck	010100	Barrow Island, WA
West Lewis Island Pastoral Settlement	010107	Dampier, WA
Register of the Heritage Council WA		
Black Hawke Bay	8662	Gidley Island, Dampier Archipelago
Uniting Church	15211	Padbury Way, Karratha
Dampier Fire Station	14493	High St, Dampier
Dolphin Island Grave Site	8667	Dolphin Island, off Burrup Peninsula
Karratha Fire Station	14528	Welcome Rd, Karratha
Karratha War Memorial	13822	Welcome Rd, Karratha
Kindergarten and Church	15212	Church Rd, Dampier
Malus Island – Whaling Site	4585	Mermaid Sound, Dampier Archipelago
Manse	15213	Padbury Way, Karratha
Pegs Well (Ruins)	8678	Hedland Place, Karratha
West Lewis Island Pastoral Settlement (Ruins)	8691	Mermaid Sound, Dampier Archipelago
Tambrey Centre	16777	Lot 4227 Tambrey Dve Karratha

The nearest registered historical sites to the Pluto LNG Development are: Dampier Fire Station, Kindergarten and Church and the Uniting Church in Dampier, all approximately 7.5 km from Site A and Site B (**Figure 10-1**).

10.5 Land Use and Tenure

Land use planning for the Burrup Peninsula is guided by a number of planning strategy documents that have been developed over the past ten years; the following documents provide a direction for planning in Karratha as well as the Burrup Peninsula in general:

- Burrup Peninsula Land Use Plan and Management Strategy (BPMAB 1996)
- Pilbara Land Use Strategy (PDC 1997)
- State Planning Strategy (WAPC 1997)
- Karratha Area Development Strategy (WAPC 1998).

The Burrup Peninsula Land Use Plan and Management Strategy (BPMAB 1996) provides specific planning strategies and guidance for development on the Burrup Peninsula. This Strategy was developed for the allocation of vacant crown land to assist in meeting the strategic industrial land requirements of the State and to preserve the quality of the outstanding natural resources and cultural heritage while also providing for the recreational and educational needs of the general public.

Five industrial areas, covering a total area of 1820 ha, have been identified by government for future industry use with each area having defined development values and management objectives (BPMAB 1996).

Land tenure and use for the various aspects of the Development are as follows:

Offshore

The Pluto gas field is located in exploration permit WA-350-P, and is 100% operated by Woodside. This will be converted into a production licence once field development planning activities are sufficiently mature for a production licence application to be made with DoIR. Several oil and gas production facilities and undeveloped hydrocarbons discoveries exist in the region (**Figure 10-2**). The proposed gas trunkline route will also traverse permits operated by other petroleum companies. The platform will be located in relatively shallow water (80–85 m) on the continental shelf within an infrastructure licence some 27 km from the Pluto gas field.

Onshore Gas Trunkline Corridor

The gas trunkline Option 1 will transect through the NWSV Karratha Gas Plant lease area prior to entering Site B. The gas trunkline Option 2, which has a landfall at Holden Point, will transect Site A and Site B, crossing the NWSV Haul Road which is leased by the NWSV.

Site B

Site B is located on land currently designated as unallocated Crown land; within an industrial-zoned area, as defined by the Burrup Land Use Plan and Management Strategy (BPMAB 1996). Much of the Burrup Peninsula is classified as Conservation, Heritage and Recreation Reserve under the strategy. Site B covers approximately 130 ha and is approximately 6 km (straight line distance) from the nearest residential areas in the town of Dampier.

Several other industries are well-established in the area including Burrup Fertiliser's recently commissioned Ammonia Plant, Dampier Salt (Australia's largest single salt producer) and the iron ore handling, port and rail facilities operated at Dampier by Hamersley Iron and Pilbara Rail (**Figure 10-3**).

Site A

Site A covers approximately 61 ha and is zoned as 'industrial' under the Burrup Land Use Plan and Management Strategy (BPMAB 1996). Several petroleum and marine related industries are currently located in the vicinity of Site A.

To the north of Site A is the existing NWSV Karratha Gas Plant. The land immediately to the north and east of Site A is not fully developed. The eastern boundary of Site A is defined by the NWSV Haul Road held under lease by the NWSV. The East West Service Corridor abuts the southern boundary of Site A. To the south-west is land owned by the DPA which is proposed for development. To the west of the site are existing shipping channels and export facilities associated with industrial development in the region (**Figure 10-3**).

10.6 Protected Areas

The Pluto LNG Development will be located in the vicinity of a number of areas which are relatively pristine and are formally protected under legislation and include marine parks, nature reserves, national parks, heritage places and conservation areas.

Figure 10-1 Historical Places on the Burrup Peninsula, Karratha and Dampier Region

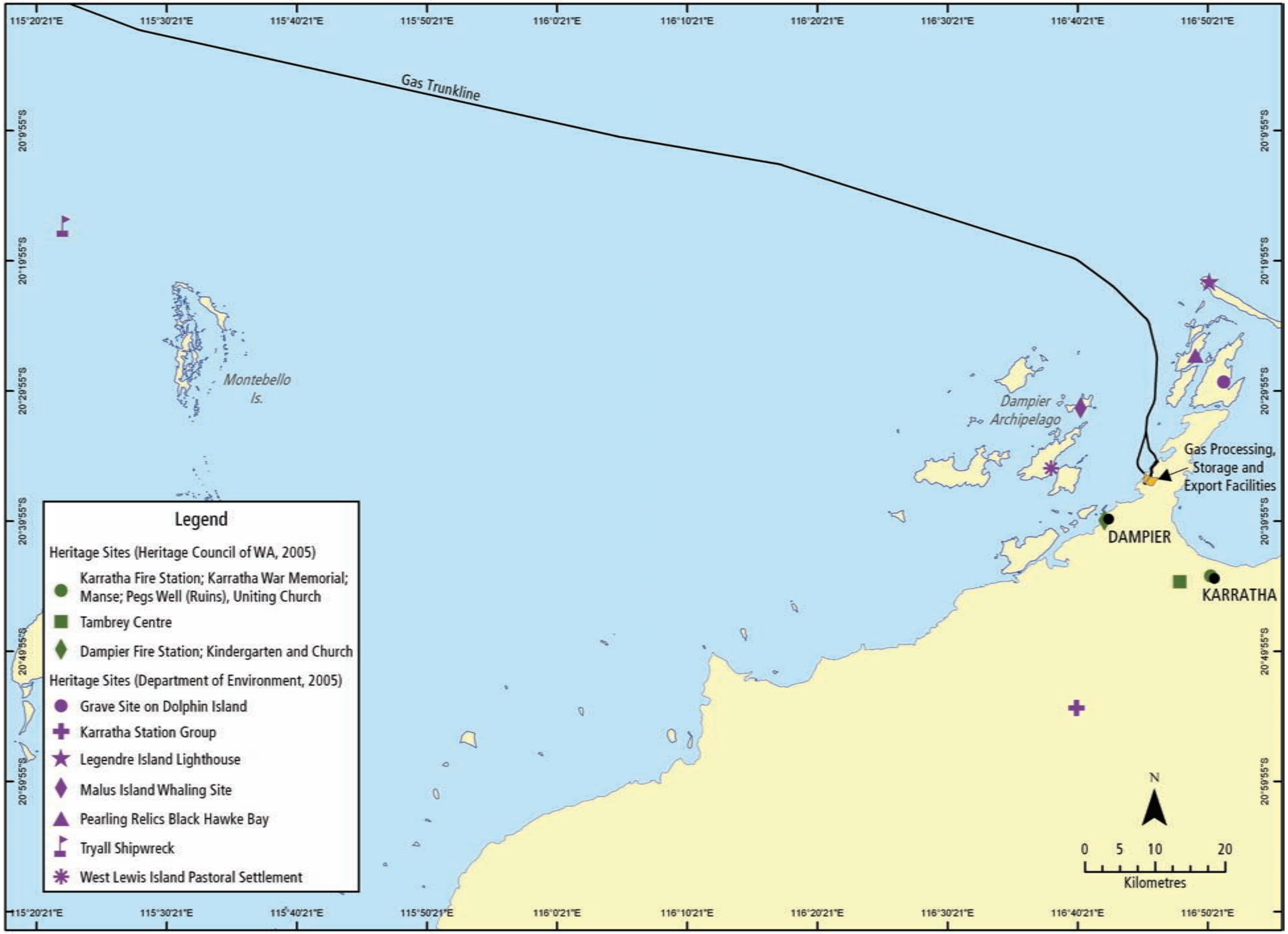


Figure 10-2 Offshore Oil and Gas Facilities on the North West Shelf

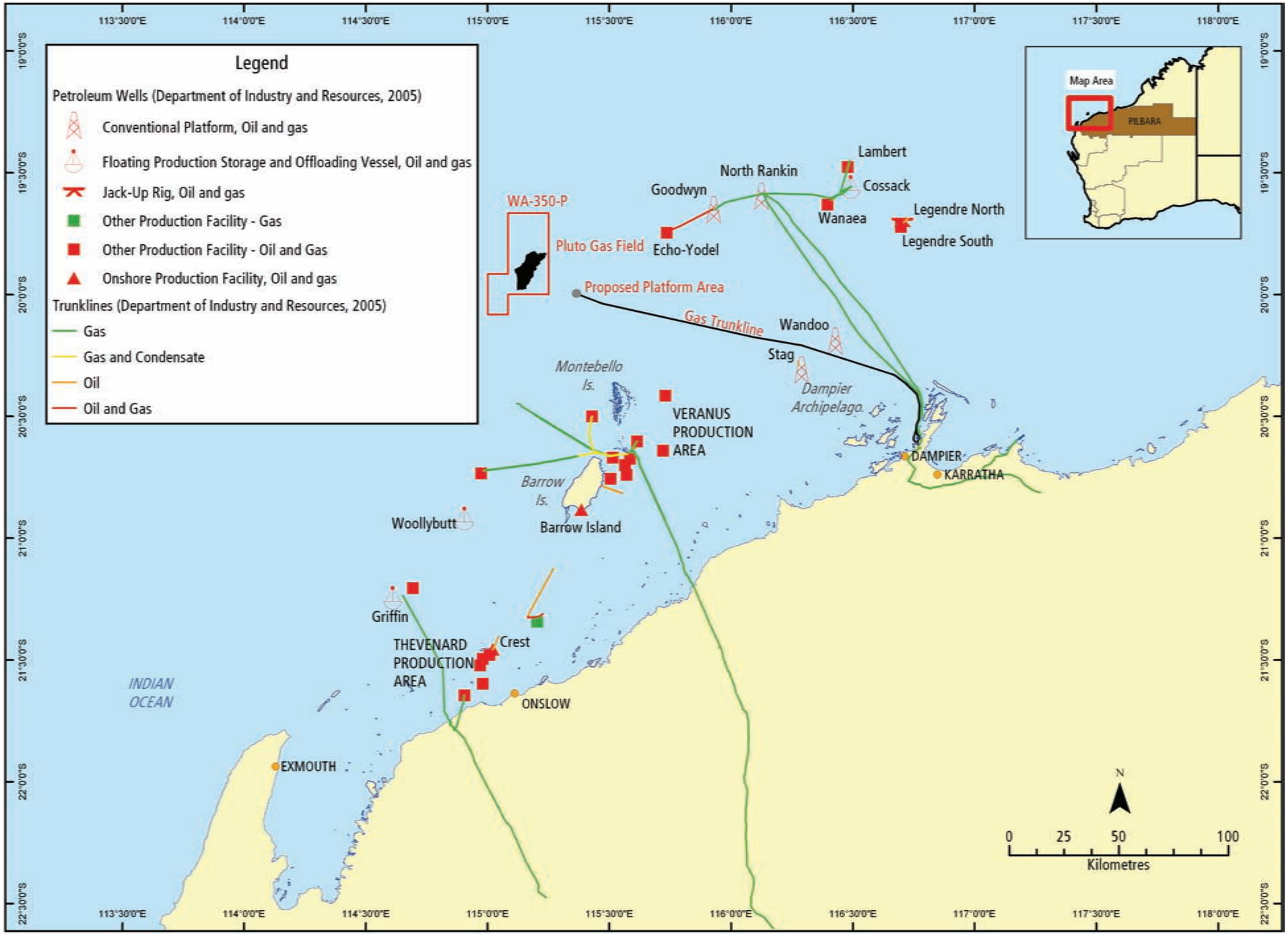
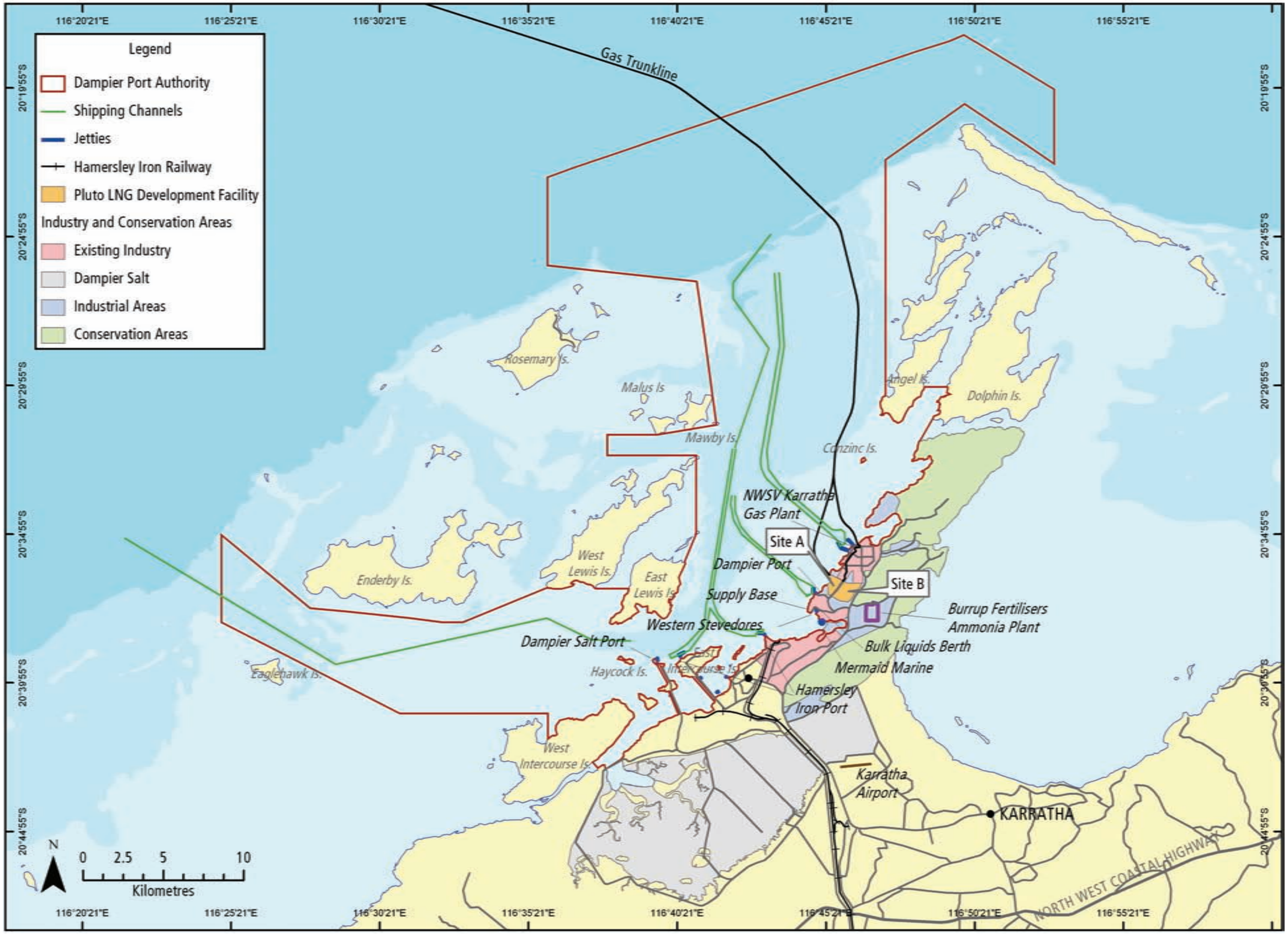


Figure 10-3 Existing Industry and Industrial Zones



Marine Parks

The Pilbara coast is generally remote from infrastructure, rugged and inaccessible, and contains marine environments and offshore islands that are recognised as having high environmental value. These values are reflected in an extensive network of existing and proposed conservation areas along the entire Pilbara coast which include: Ningaloo Reef Marine Park, Muiron Islands Marine Management Area, Cape Range National Park, Montebello/Barrow Islands Marine Conservation Reserves, Cape Preston Marine Management Area (proposed) and Dampier Archipelago Marine Park (proposed).

Marine parks and reserves are protected under the *Conservation and Land Management Act 1984* (WA) and are vested in the Marine Parks and Reserves Authority. The DEC manages marine parks and reserves on behalf of the Marine Parks and Reserves Authority. Marine parks aim to protect natural features while also allowing recreational and commercial uses that do not compromise conservation values, whilst marine management areas provide an integrated management framework over areas with high conservation value that also have intensive multiple-use. **Table 10-11** shows distances from the closest point of the proposed development to each of these conservation areas.

The Dampier Archipelago has the richest marine biodiversity known in Western Australia (CALM 2000). The proposed Dampier Archipelago-Cape Preston Marine Conservation Reserves contains a wide range of habitats including mangroves, algal meadows, sandy beaches, submerged soft sediment communities, coral reefs, diverse invertebrate communities, rocky shores and rocky reefs.

The zoning of the proposed Dampier Archipelago Marine Park comprises seven sanctuary zones, one special purpose (mangrove protection) zone, four special purpose (benthic protection) zones, two special purpose (intertidal reef protection) zones, three special purpose (pearling or aquaculture) zones, two recreation zones and one special purpose (multiple use) zone. All other areas in the marine park not included in the sanctuary, recreation, or special purpose zones are designated for general use (approximately 50% of the marine park).

The zoning of the proposed Cape Preston Marine Management Area comprises two conservation (flora/fauna protection) areas, one conservation (mangrove protection) area, and two commercial (aquaculture) areas. The remaining area (approximately 82% of the marine management area) is unzoned. Marine parks and management areas in the region are represented in **Figure 10-4**.

Nature Reserves and National Parks

There are a number of nature reserves in the region (**Figure 10-5**). Terrestrial nature reserves and National Parks are protected under the *Conservation and Land Management Act 1984* (WA) and vested in the Conservation Commission for the protection of flora and fauna. The DEC manages nature reserves and National Parks on behalf of the Conservation Commission. Nature reserves in the region include:

- Dampier Archipelago Nature Reserve
- Great Sandy Islands Nature Reserve
- Thevenard Island Nature Reserve
- Bessieres Island Nature Reserve
- Locker Island Nature Reserve
- Round Island Nature Reserve
- Serrurier Island Nature Reserve
- Lowendal Islands Nature Reserve
- Thevenard Island Nature Reserve
- Barrow Island Nature Reserve.

The Dampier Archipelago Nature Reserve lies within 1 km of the Pluto LNG Development while the other nature reserves are greater than 49 km from the Development. Approximately 25 of the islands in the Dampier Archipelago are incorporated into four nature reserves which are vested in the National Parks and Nature Conservation Authority (NPNCA), and managed by the DEC. The nature reserves vary in size as follows:

- Class A Nature Reserve 36915 has a total area of 4436 ha and includes Enderby Island and most of Rosemary Island

Table 10-11 Distance to Marine Parks and Management Areas

Conservation Reserve	Approximate distance from Pluto LNG Development (km)
Ningaloo Reef Marine Park	220
Muiron Islands Marine Management Area	220
Cape Range National Park	258
Montebello/Barrow Islands Marine Conservation Reserve	17.5
Cape Preston Marine Management Area (proposed)	17
Dampier Archipelago Marine Park (proposed)	1.5

- Class B Nature Reserve 34944 has a total area of 3203 ha and includes all of Dolphin Island
- Class C Nature Reserve 36913 has a total area of 3020 ha and includes numerous smaller islands
- Class C Nature Reserve 39202 has a total area of 11 ha and comprises all of Cohen Island

All of the nature reserves extend to low water mark. Recommendations have also been made for these islands to be designated as national parks (Morris 1990); however, the closest National Park to the Pluto LNG Development is currently the Millstream-Chichester National Park, approximately 65 km to the south-east.

Heritage Places

The Heritage Council of WA considers places for entry in the Register of Heritage Places based on a number of criteria including aesthetic, social, scientific and historic values. The physical condition integrity and authenticity of places is also taken into account in assessing a place for registration; however it is possible for a place of poor condition or integrity to be entered in the register where other values are high (for example, historic value or rarity).

A search of the Australian Heritage Database and the Heritage Council of Western Australia's 'Places Database' for the Dampier and the Burrup Peninsula regions revealed a number of listed places. Places classed as 'natural' are detailed in **Table 10-12** and shown in **Figure 10-6** while those classed as 'Indigenous' and 'historical' are detailed in **Section 10.3** and **Section 10.4**, respectively.

The Dampier Archipelago is registered on the Register of the National Estate and is located in close proximity to the Pluto LNG Development. The Archipelago consists of a group of ten large and many small islands with significant flora and fauna diversity and surrounding coral reefs.

Areas classified as 'indicative places' have been nominated for inclusion in the Register of the National Estate but have not yet been assessed. This includes the Dampier Archipelago Marine Area which covers about 375 000 ha and encompasses the seabed, reefs, intertidal zone and adjacent marine areas of the Dampier Archipelago islands. Another 'indicative' place on the Register of the National Estate is the Coastal Margin Cape Preston to Cape Keraudren, which covers a total area of 60 000 ha stretching 400 km north-east and south-west of Port Hedland and including the tidal flats and mangroves between Cape Preston and the Burrup Peninsula.

The proposed Dampier Archipelago–Cape Preston Marine Conservation Reserve covers a similar area to the 'indicative' Dampier Archipelago Marine Area, however it would be provided with State protection under the *Conservation and Land Management Act 1984* (WA), as opposed to the Commonwealth protection provided by the Register of the National Estate.

Table 10-12 Listed Places on the Register of National Estate (contained in the Australian Heritage Database) and the Heritage Council of Western Australia's 'Places Database'

Place Name	ID Number	Status	Location	Distance from Pluto LNG Development (km)
Register of the National Estate				
Coastal Islands Mary Anne to Regnard	010109	Registered	Mardie, WA	50
Coastal Margin Cape Preston to Cape Keraudren	017917	Indicative Place	Port Hedland, WA	0
Dampier Archipelago Marine Areas	017563	Indicative Place	Dampier, WA	1
Dampier Archipelago	010101	Registered	Dampier, WA	1
Lowendal Islands and Adjacent Marine Areas	017419	Indicative Place	Barrow Island, WA	58
Lowendal Islands	010098	Registered	Barrow Island, WA	58
Montebello Islands Marine Area	017565	Registered	Barrow Island, WA	31.5
Montebello Islands	010099	Registered	Barrow Island, WA	34
Register of the Heritage Council WA				
Enderby Island	8668	Registered	Mermaid Strait, Dampier Archipelago	17
North West Shelf, Burrup Peninsula	12666	Registered	Burrup Peninsula, Dampier	0
Burrup Peninsula and Hearsons Cove	08663	Registered	Hearson Cove Rd, Burrup Peninsula	0

Source: the Australian Heritage Database 2005 and the Heritage Council of Western Australia's 'Places' Database 2005

Figure 10-4 Marine Parks and Management Areas in the Vicinity of the Pluto LNG Development

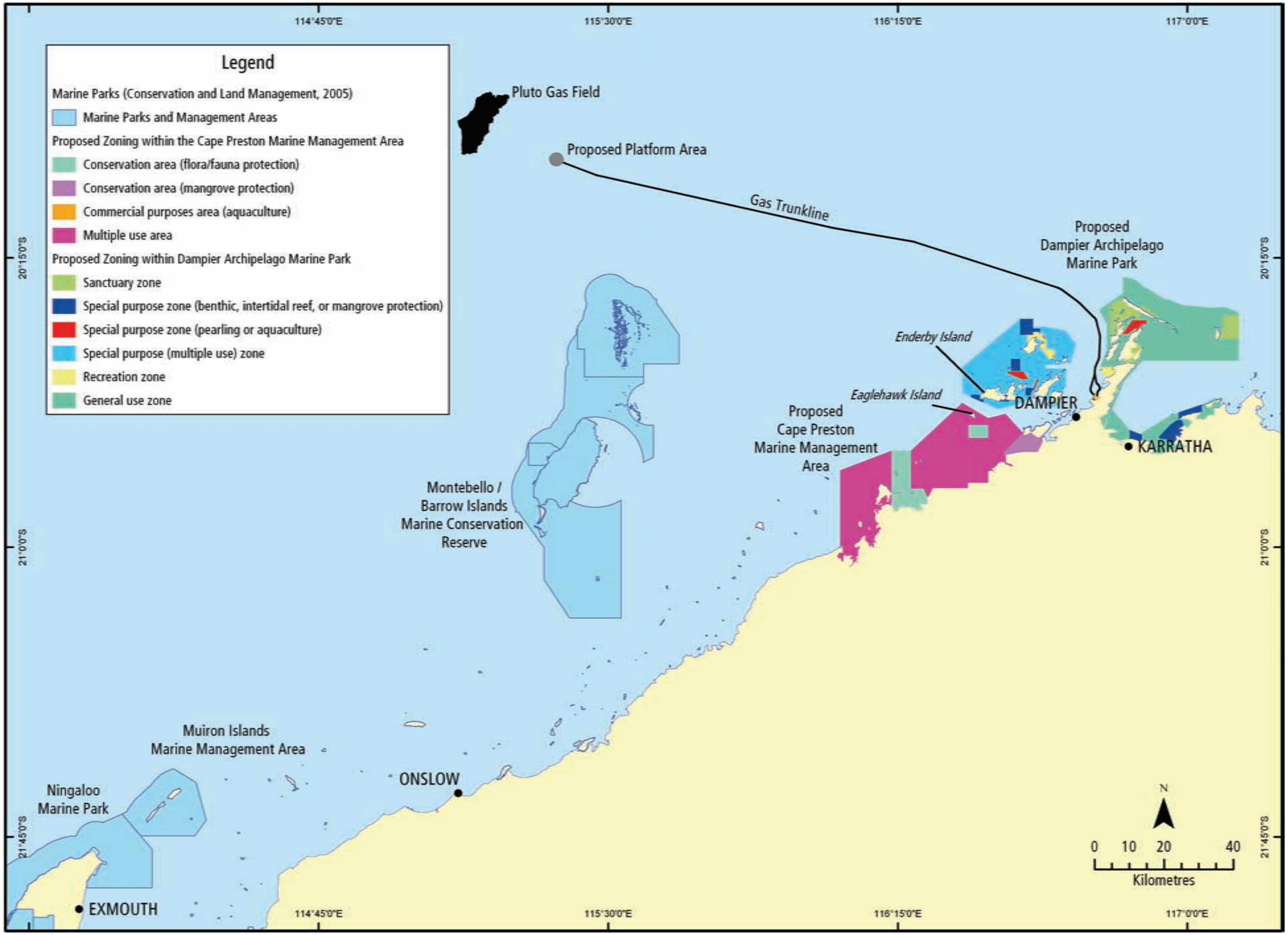


Figure 10-5 Nature Reserves in the Vicinity of the Pluto LNG Development

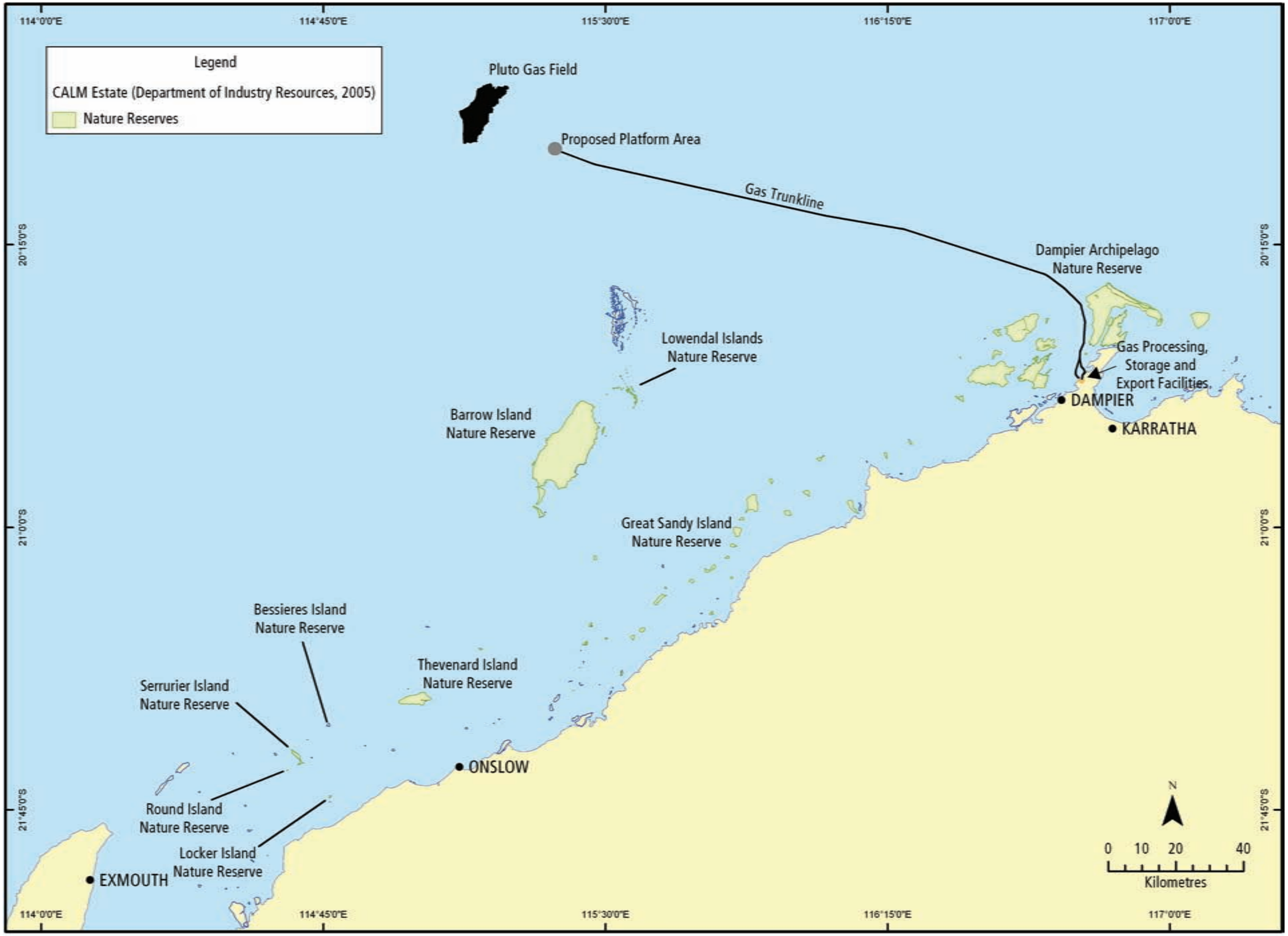
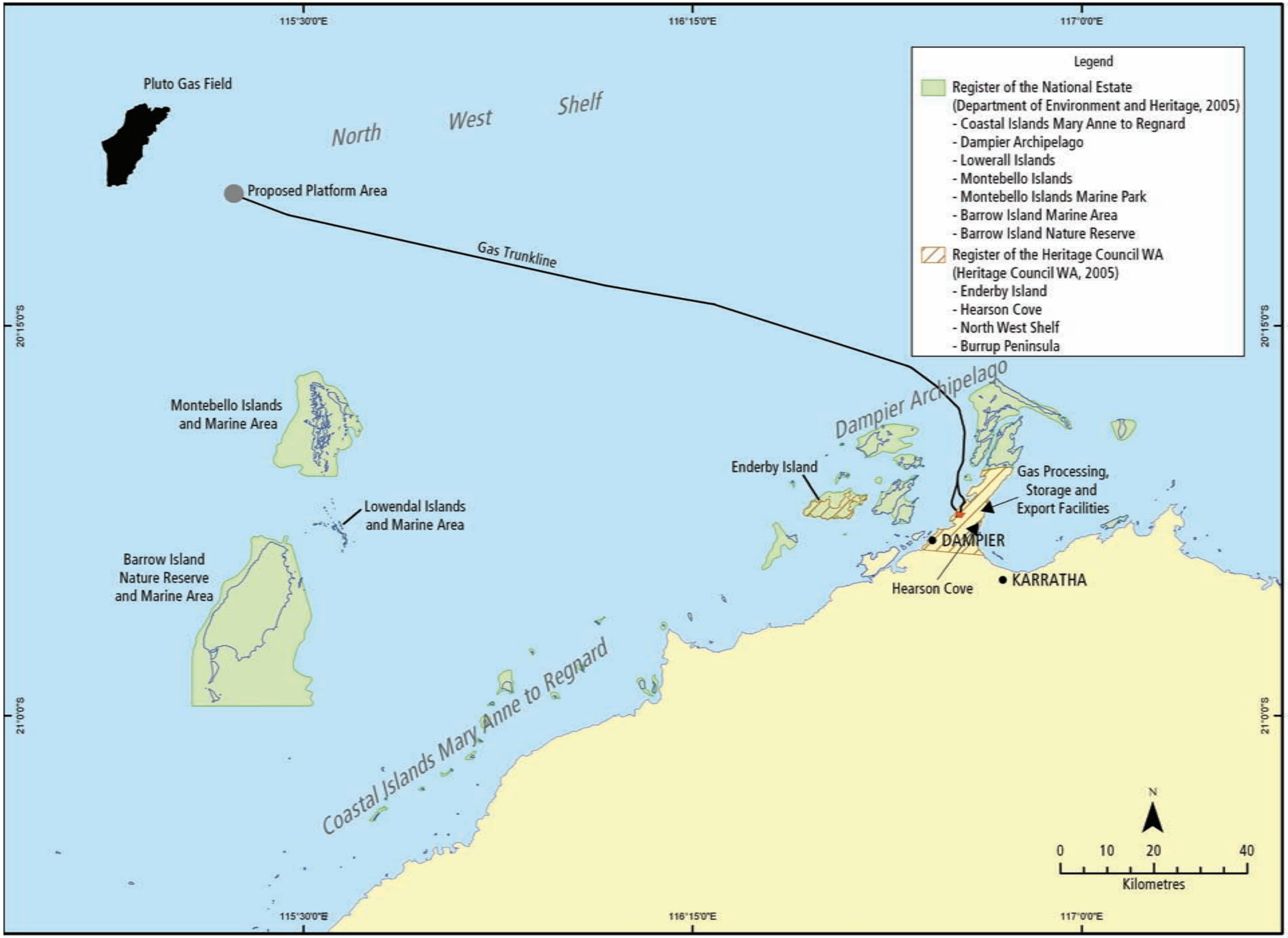


Figure 10-6 Natural Places Listed on the Register of the National Estate and the Register of the Heritage Council WA



Conservation Areas

The Burrup Land Use Plan and Management Strategy (BPMAB 1996) allocates much of the Burrup Peninsula to a Conservation, Heritage and Recreation Reserve. This area covers approximately 5400 ha (62%) of the northern, central and southern parts of the Burrup Peninsula. In addition to this designation, the Plan *'provides management objectives and outlines acceptable uses and development considerations (Policy Statements) for all areas'*.

In January 2003, the Burrup and Maitland Industrial Estates Agreement was settled. As part of this agreement, non-industrial land of the Burrup Peninsula (that is, the Conservation, Heritage and Recreation Reserve identified in the Burrup Land Use Plan and Management Strategy) is proposed as freehold land vested in an Aboriginal Approved Body Corporate, comprising members of three Traditional Custodians; the Wong-Goo-Tt-Oo, the Yaburarra Mardudhunera and the Ngarluma Yindjibarndi.

The non-industrial land is also proposed for the Burrup Peninsula Conservation Reserve, which covers approximately 62% of the Burrup Peninsula. This will give the non-industrial areas of the Burrup Peninsula, as outlined in the Burrup Land Use Plan and Management Strategy, protection under the *Conservation and Land Management Act 1984* (WA). The proposed Burrup Peninsula Conservation Reserve will be jointly managed by the Traditional Custodians and the DEC.

Under the Burrup and Maitland Industrial Estates Agreement, a management plan is required for the non-industrial areas. In order to meet this requirement, a draft management plan for the proposed Burrup Peninsula Conservation Reserve was released in 2006 (DEC 2006). The draft management plan was available for public comment until September 2006.

Site B and Site A are located approximately 2 km from the proposed Burrup Peninsula Conservation Reserve (**Figure 10-7**).

10.7 Fisheries

10.7.1 A Summary of the Fisheries of the North West Shelf

Catches from the Pilbara fisheries dominate the current Western Australian metropolitan markets and support the local fish processing sector. The export of scale fish to Europe and Asia is also becoming increasingly important. The principal fisheries in the Pilbara region target tropical finfish, tuna and other large pelagic species, and crustaceans (prawns and scampis) as well as the lucrative pearl oyster.

The Pilbara Fish Trawl (Interim) Managed Fishery and the Pilbara and Northern Demersal Trap Fisheries, which cover the Pilbara and Kimberley regions, together catch in the order of 3000 tonnes annually, making these fisheries, at an estimated annual value of around A$12 million, the most valuable finfish sector in the state. A number of wetline activities, including longlining for mackerel and snapper species, also occur in the region.

Commercial fishing vessels in the area operate mainly out of the ports of Dampier, Onslow, Point Samson and Exmouth. Recreational fishing is also a significant marine activity in the Pilbara and is experiencing significant growth. Aquaculture in the region is currently dominated by pearl oyster activities.

The management of commercial fisheries is divided between the Western Australian Department of Fisheries (DFWA) and the Commonwealth Australian Fisheries Management Authority (AFMA). The DFWA is responsible for fisheries in coastal waters 3 nm from the territorial baseline, while AFMA manages fisheries beyond 3 nm to the extent of the Australian Fishing Zone (200 nm from the mainland and territorial coasts) (**Figure 10-8**).

A number of restriction and exclusion zones exist in the region, with extensive temporal and spatial restrictions imposed by DFWA for various fisheries, in an effort to ensure sustainability within the industry (**Figure 10-8**).

Fisheries in the region are represented by a number of commercial fishing associations including:

- Western Trawl Fisheries Management Advisory Committee (WestMAC)
- Tuna Boat Owners Association of Australia
- Western Australia Fishing Industry Council
- Western Australian Northern Trawl Owners Association
- Tuna West
- Western Australia Pelagic Longliners Association
- Northern Fishing Companies Association.

Figure 10-7 The Burrup Land Use Plan and Management Strategy Zoning

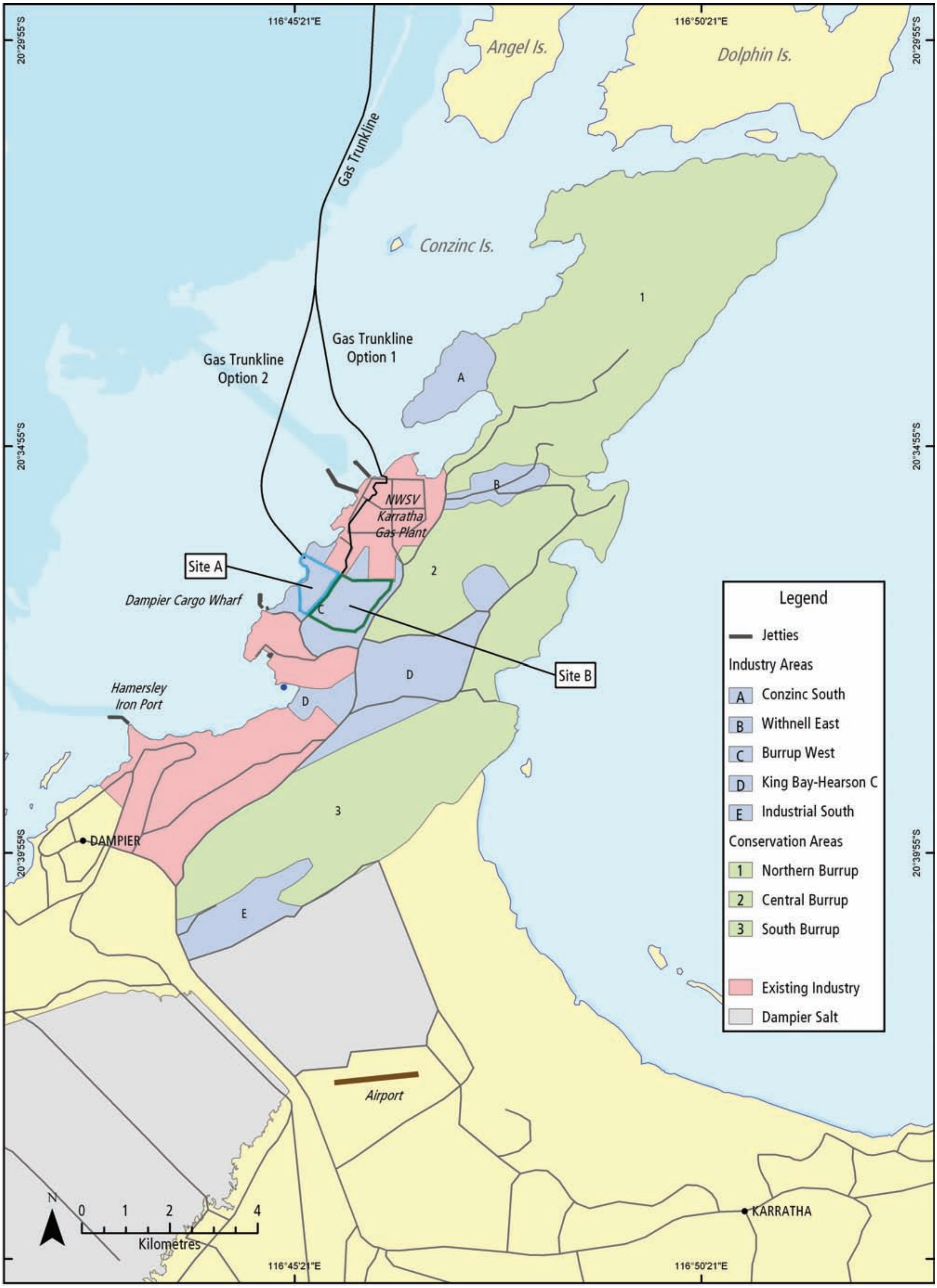
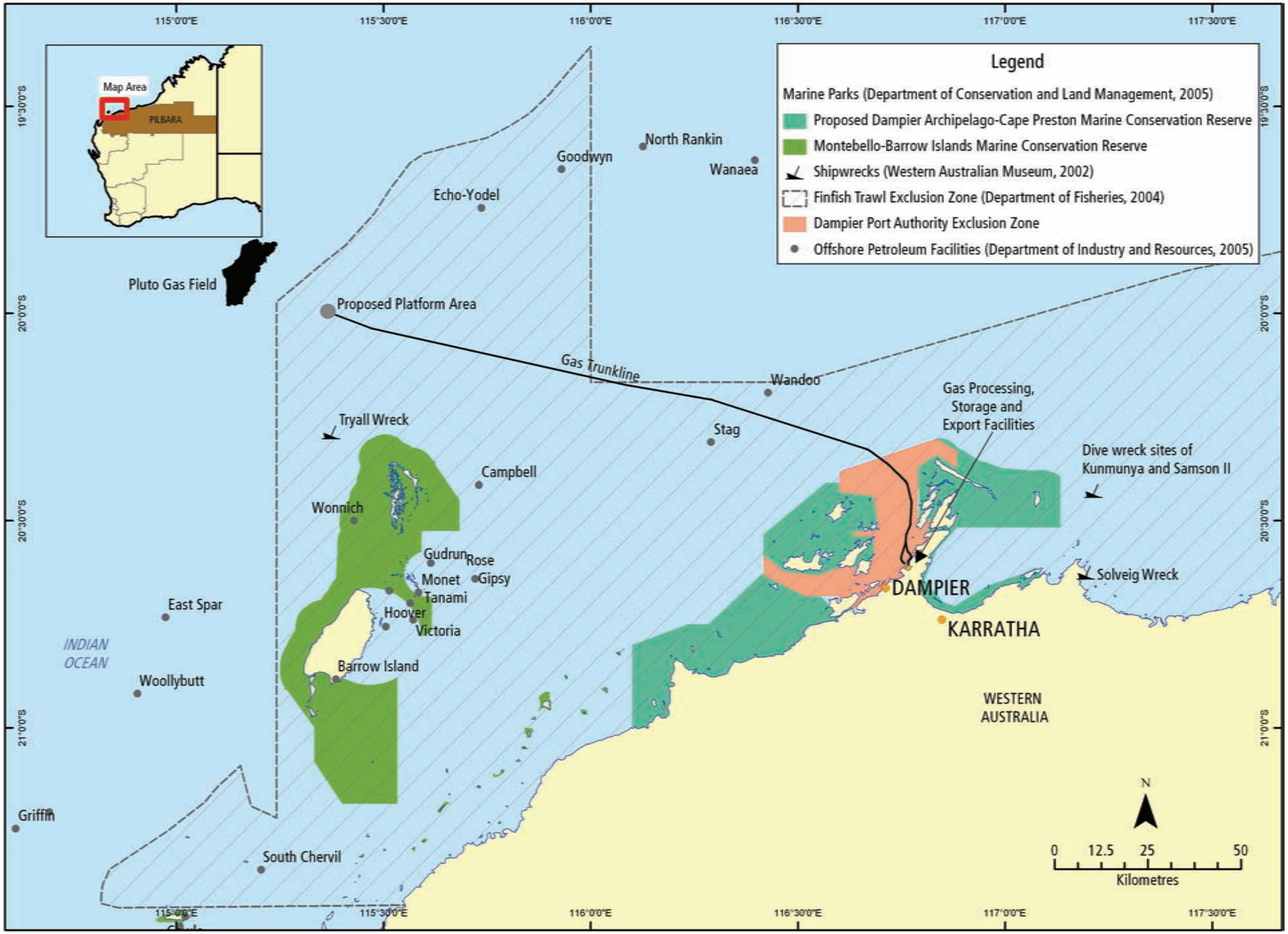


Figure 10-8 Fishing Restricted Areas on the North West Shelf



10.7.2 Commonwealth Fisheries

The AFMA manages a number of fisheries that include the North West Shelf within their boundaries. Of these, four overlap either part or all of the offshore Pluto LNG Development areas. They are:

- the North West Slope Trawl Fishery
- the Western Tuna and Billfish Fishery
- the Southern Bluefin Tuna Fishery
- the Skipjack Tuna Fishery.

Of these only the North West Slope Trawl Fishery (NWSTF) has significant fishing activity in the Development area (A Hepp [Environmental Officer AFMA] pers. comm., 24 November 2005).

Northwest Slope Trawl Fishery

The NWSTF extends from 114°E to about 125°E off the Western Australian coast, between the 200 m isobath and the outer limit of the AFZ (AFMA 2005a) (**Figure 10-9**). The main target species for this fishery are various scampi species (*Metanephros* spp.) and deepwater prawns such as penaeid species (*Aristaeomorpha foliacea*, *Haliporoides sibogae*, *Aristeus virilis* and *Plesiopenaeus edwardsianus*) and carid species (*Heterocarpus woodmasoni* and *H. sibogae*)

Most vessels tend to operate in 200–300 m of water. There are currently seven permits to trawl in this fishery; six of these are endorsements on Northern Prawn Fishery licences and consequently most of the fishing effort occurs during the off-season for the Northern Prawn Fishery; mid-June to July and December to April, though some level of effort does occur year round (Evans 1992; A Hepp [Environmental Officer AFMA] pers. comm., 18 November 2005).

Vessels fishing in the NWSTF, operate within the Pluto gas field. Historical AFMA logbook data indicates that up to four vessels may fish within the area of the Pluto LNG Development over a period of one month (A Hepp [Environmental Officer AFMA] pers. comm., 24 November 2005).

Western Tuna and Billfish Fishery

The Western Tuna and Billfish Fishery (WTBF) generally extends northwards from 34°S off the west coast of Western Australia to 42°30'E at Cape York Peninsula off Queensland, encompassing the Pluto LNG Development area (Lynch 2004). The principal target species are broadbill swordfish (*Xaphias gladius*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*), albacore tuna (*T. alalunga*) and longtail tuna (*T. tonggol*). This fishery uses pelagic longline, minor line and purse seine techniques (A Hepp [Environmental Officer, AFMA] pers. comm., 18 November 2005).

A search of the historical AFMA logbook data for 2003 and 2004 indicated that the WTBF was active within the area of the Pluto LNG Development with the most fishing intensive areas being between 200 m and 500 m depth (A Hepp [Environmental Officer, AFMA] pers. comm., 18 November 2005).

The Southern Bluefin Tuna Fishery is an international fishery, managed since 1994 by the Commission for the Conservation of Southern Bluefin Tuna (Caton and Mcloughlin 2004). The Southern Bluefin Tuna fishery extends around the entire Australian coastline, however, approximately 98% of Australia's quota is taken in the Great Australian Bight (AFMA 2005b). Generally no fishing occurs within the vicinity of the proposed Pluto LNG Development (A Hepp [Environmental Officer AFMA] pers. comm., 18 November 2005).

Skipjack Tuna (Western)

The Skipjack Tuna Fishery is currently under the management arrangements of the Eastern Tuna and Billfish Fishery and the Southern and Western Tuna and Billfish Fishery (AFMA 2002). The combined area of these fisheries covers the entire AFZ and while this encompasses the entire Pluto LNG Development, no fishing generally occurs within the Development area (A Hepp [Environmental Officer, AFMA] pers. comm., 18 November 2005).

10.7.3 Western Australian State Managed Fisheries

The DFWA manages several fisheries on the North West Shelf, of which six have boundaries that overlie or are in close proximity to part or all of the offshore area of the Pluto LNG Development, they include:

- the Pilbara Demersal Finfish Fishery comprising:
  - the Pilbara Fish Trawl (Interim) Managed Fishery
  - the Pilbara Trap Managed Fishery
- the Onslow Prawn Managed Fishery
- the Nickol Bay Prawn Fishery
- the Pearl Oyster Fishery
- the Western Australian Mackerel Fishery
- the North Coast Shark Fishery.

Pilbara Fish Trawl (Interim) Managed Fishery

The majority of the demersal finfish caught in the Pilbara region are taken by the Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF), the boundaries of which are the waters lying north of latitude 21°35' S between longitudes 114°9'36" E and 120° E on the landward side of a boundary approximating the 200 m isobath seaward of a line following the 50 m isobath (**Figure 10-10**).

Figure 10-9 North West Slope Trawl Fishery

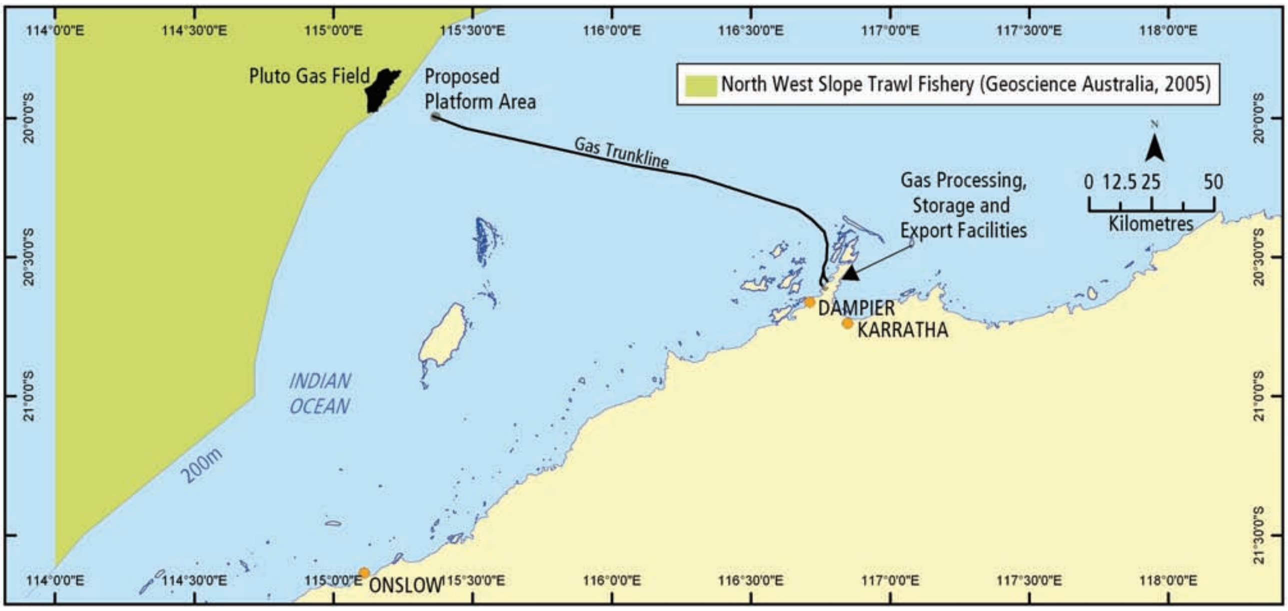
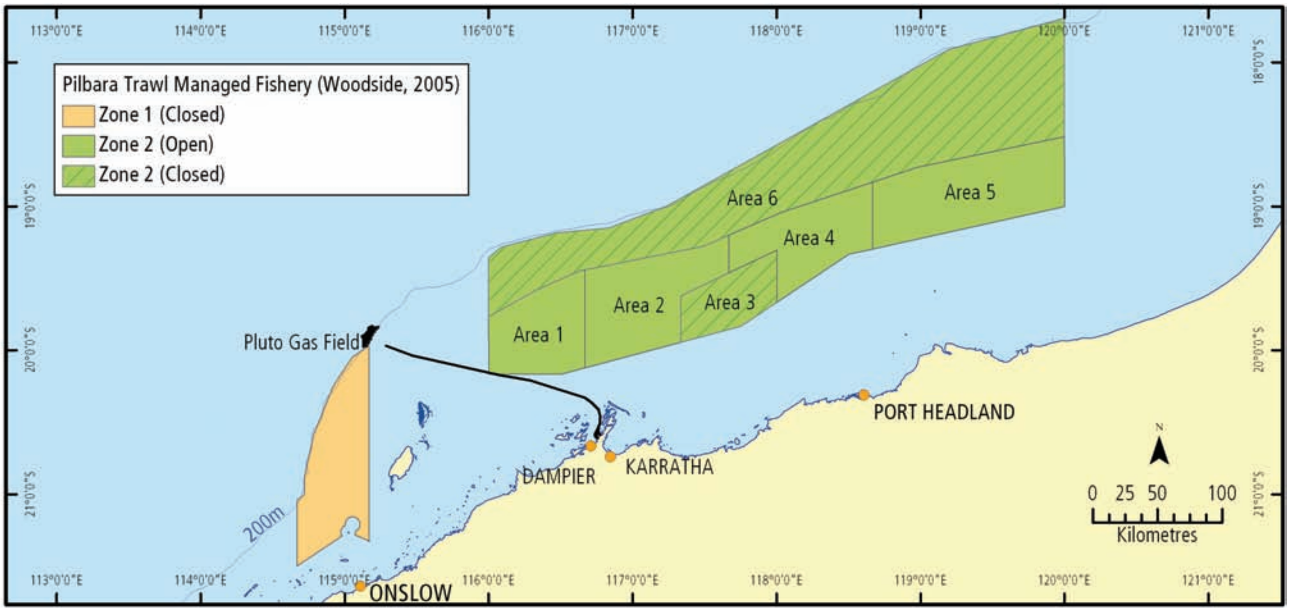


Figure 10-10 Pilbara Fish Trawl (Interim) Managed Fishery



The PFTIMF targets ten main species, namely blue-spot emperor (*Lethrinus hutchinsi*), threadfin bream (*Nemipteridae*), flagfish (*Lutjanus vitta*), red snapper (Lutjanus erythropterus), red emperor (*Lutjanus sebae*), scarlet perch (*Lutjanus malabaricus*), goldband snapper (*Pristipomoides multidens*), spangled emperor (*Lethrinus nebulosus*), frypan snapper (*Argyrops spinifer*) and Rankin cod (*Epinephelus multinotatus*).

The PFTIMF consists of two zones. Zone 1, in the west of the fishery, is currently closed to trawling. Zone 2 is subdivided into six management sub-areas according to an interim management plan introduced in 1998. Area 3, area 6, and the area inshore of the 50 m depth isobath have been closed since 1988. Areas 1, 2, 4 and 5 remain open year round, with different effort allocations in each area and reduced effort in April and May when most vessels move to operate in the Nickol Bay Prawn Managed Fishery. At present the fleet consistently covers Areas 1, 2 and 4 but only about 80% of Area 5 (DoF 2004). Exclusion zones around existing gas pipelines and facilities and occasional restrictions due to seismic surveying, can restrict fishing operations in the area but are not expected to have significant impacts on catches (Penn et al. 2005). The gas trunkline will cross Area 1 approximately 1 km into its south-west boundary.

There are 11 licence units with varying time allocations throughout the various areas, with the allocation being used by the equivalent of four full-time vessels. In 2003 a total of 20 159 hours fishing effort was recorded by this fishery (Penn et al. 2005). Catch for the PFTIMF in 2003 was 2860 tonnes and was valued at $9.1 million (Penn et al. 2005). The PFTIMF is managed by Western Australia under an Offshore Constitutional Settlement between the Australian Government and the Government of Western Australia.

Pilbara Trap Managed Fishery

The Pilbara Trap Managed Fishery (PTMF) lies north of latitude 21°44′ S and between longitudes 114°9′36″ E and 120° E on the landward side of a boundary approximating the 200 m isobath and seaward of a line generally following the 30 m isobath. The main catch in the PTMF comprises six of the same species as the PFTIMF (blue-spot emperor, spangled emperor, red emperor, Rankin cod, red snapper and goldband snapper).

The PTMF utilises rectangular traps made of galvanised steel mesh. The number of licences for this fishery is limited to six, with all licenses currently allocated to two operators. The season is open year round.

Fishing activity occurs within the area of the Pluto gas field, the proposed platform area and along the gas trunkline generally in waters further than 60 km off the mainland coast (J King [DFWA] pers. comm., 13 December 2005).

Western Australian Mackerel Fishery

While the Western Australian Mackerel Fishery (WAMF) at this stage has no formal boundaries, it extends to the limits of the AFZ and catches are reported in four areas: Kimberley (121° E to WA/NT border); Pilbara (114° E to 121° E); Gascoyne (27° S to 114° E) and west coast (Cape Leeuwin to 27° S) (Penn et al. 2005). In practice fishing occurs within continental shelf waters where mackerel appear in numbers in winter and generally in depths of 10–40 m (M Mackie [DoF] pers. comm., 21 November 2005).

The WAMF includes the taking of all species of the genera *Scomberomorus*, *Grammatorcynus* and *Acanthocybium*, but in the Pilbara area the only targeted species is Spanish mackerel (*Scomberomorus commerson*), which may comprise more than 90% of the catch. Mackerel are usually taken by trolling close to the surface in coastal areas around reefs, shoals and headlands. In recent years, the main catches from this area have come from the vicinity of Port Hedland.

The reported catch for 2003 was 457.2 tonnes of Spanish mackerel for all areas with the Pilbara region contributing 150 tonnes. The recorded fishing effort for 2003 in the Pilbara area was 19 boats and 703 days (Penn et al. 2005), but generally only a few boats target mackerel full-time, and in recent years there have been three main fishers with numerous part time fishers that participate in the WAMF, during the off-season of other fisheries (M Mackie [DFWA] pers. comm., 21 November 2005).

Pearl Oyster Fishery

The Western Australian pearl oyster fishery is the only remaining significant wild-stock fishery for pearl oysters in the world. The fishery is the second highest grossing fishery in Western Australia and in 2002/03 the estimated value of production was $124 million (Penn et al. 2005). It is a dive fishery operating in shallow coastal waters along the North West Shelf and targets the Indo-Pacific, silver-lipped pearl oyster (*Pinctada maxima*). The fishery is separated into four zones (**Figure 10-11**). Zone 1 lies within the Pluto LNG Development area and includes the area from the North West Cape (including Exmouth Gulf) to longitude 119°30′ E, just east of Port Hedland. There are five licensees in this zone.

The main fishing areas within Zone 1 are within Exmouth Gulf and to the west of Port Hedland; however, fishing occasionally occurs within the area of the Dampier Archipelago (approximately every 2–5 years). Levels and frequency of fishing in the Archipelago depend on whether harvest levels from other areas and production levels from pearl culture farms are sufficient to satisfy the annual quota. At its most intense, up to four boats fish in the Dampier Archipelago area at the one time; no fishing activity was recorded in the Archipelago for 2004 (A Hart [DFWA] pers. comm., 23 November 2005).

Onslow Prawn Managed Fishery

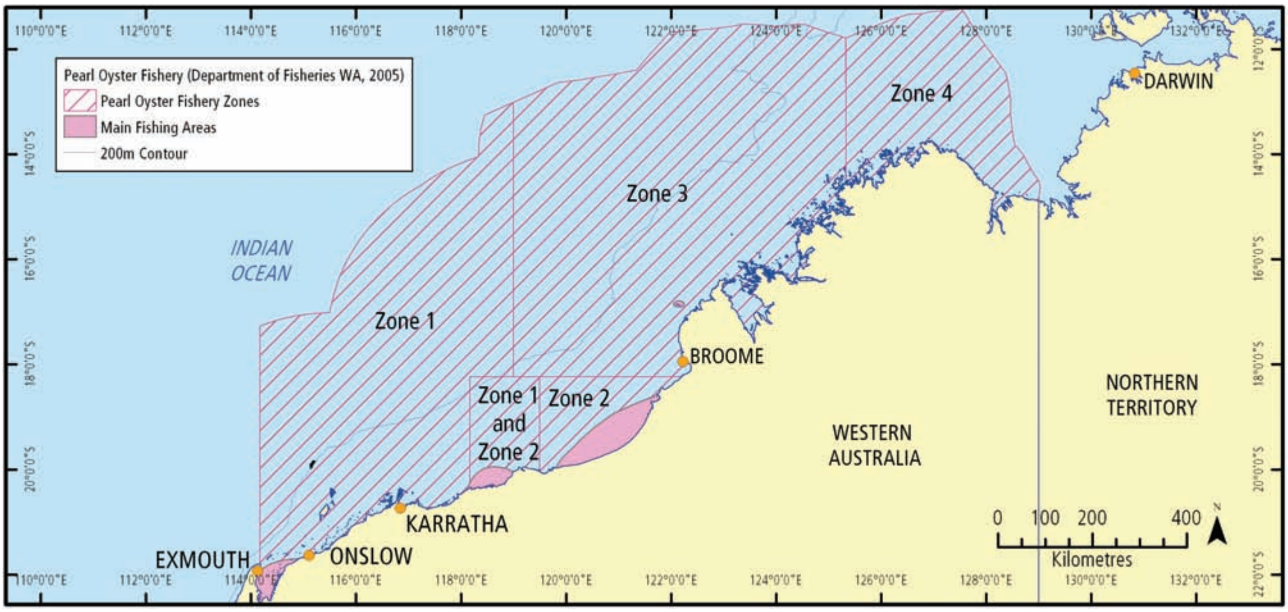
The boundaries of the Onslow Prawn Managed Fishery are presented in and include all of the Indian Ocean that lies within Western Australian waters below the high water mark west of longitude 116°45′E and east of a line drawn from the high water mark on the mainland south of Locker Island to the high water mark at the southernmost extremity of Serrurier Island and along the high water mark of Serrurier Island's western shore and due north (Penn et al. 2005).

Target species are western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus* spp.) and banana prawns (*Penaeus merguiensis*). Trawling for prawns is permitted at a number of locations and occurs on a series of small grounds associated with inshore nursery areas. The fishery has a total of 31 licensees; however, not all licensees are permitted to fish the entire range of this fishery.

The opening and closing dates for the fishery vary from year to year and are based on advice from the DFWA Research Division.

Figure 10-12 shows areas trawled during the 2004 season. Levels of activity in areas trawled within the Dampier Archipelago vary from year to year depending on prawn abundance. The area trawled within the Dampier Archipelago constitutes approximately 9.2% of the total trawled area within the fishery during 2004. Trawling grounds are permanently closed in the Port of Dampier.

Figure 10-11 North West Slope Trawl Fishery



Nickol Bay Prawn Managed Fishery

The boundaries of the Nickol Bay Prawn Managed Fishery include all the waters of the Indian Ocean and Nickol Bay between 116°45' east longitude and 120° east longitude on the landward side of the 200 m isobath. Targeted species are banana prawns (*Penaeus merguiensis*), western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*) and endeavour prawns (*Metapenaeus* spp.).

In 2003 the fleet comprised of 14 boats licensed to trawl for prawns in Nickol Bay. The total landings of major penaeids for the 2003 season was 248 tonnes (Penn et al. 2005), and the five year annual average value of landings is $2.9 million (DEH 2004).

North Coast Shark Fishery

As of the 1 July 2005, the Western Australian North Coast Shark Fishery (WANCSF) is closed between North West Cape (114° 06'E) and 120°E and east of 120°E, south of 18°S. This indefinite closure covers all offshore areas of the Pluto LNG Development and is likely to continue for a minimum of 20 years (R McAuley [Shark Research Section, DFWA] pers. comm., 14 November 2005).

Wetline Fishing

Wetlining includes line fishing and near shore beach seining and gillnetting. It occurs throughout the North West Shelf and at present any operator with a commercial fishing licence may wetline. Wetliners target the 100 m contour and nearshore islands and reefs fishing for snapper (for example, *Pristipomoides multidens*), emperor species (for example, *Lethrinus nebulosus*) and Spanish mackerel (*Scomberomorus commerson*) (Penn et al. 2005; P Stephenson [DFWA] pers. comm., 23 November 2005). Around a quarter (22%) of the state's wetline catch during 2002/03 was reported from waters off the Kimberley and Pilbara coasts (Penn et al. 2005).

Other Fisheries

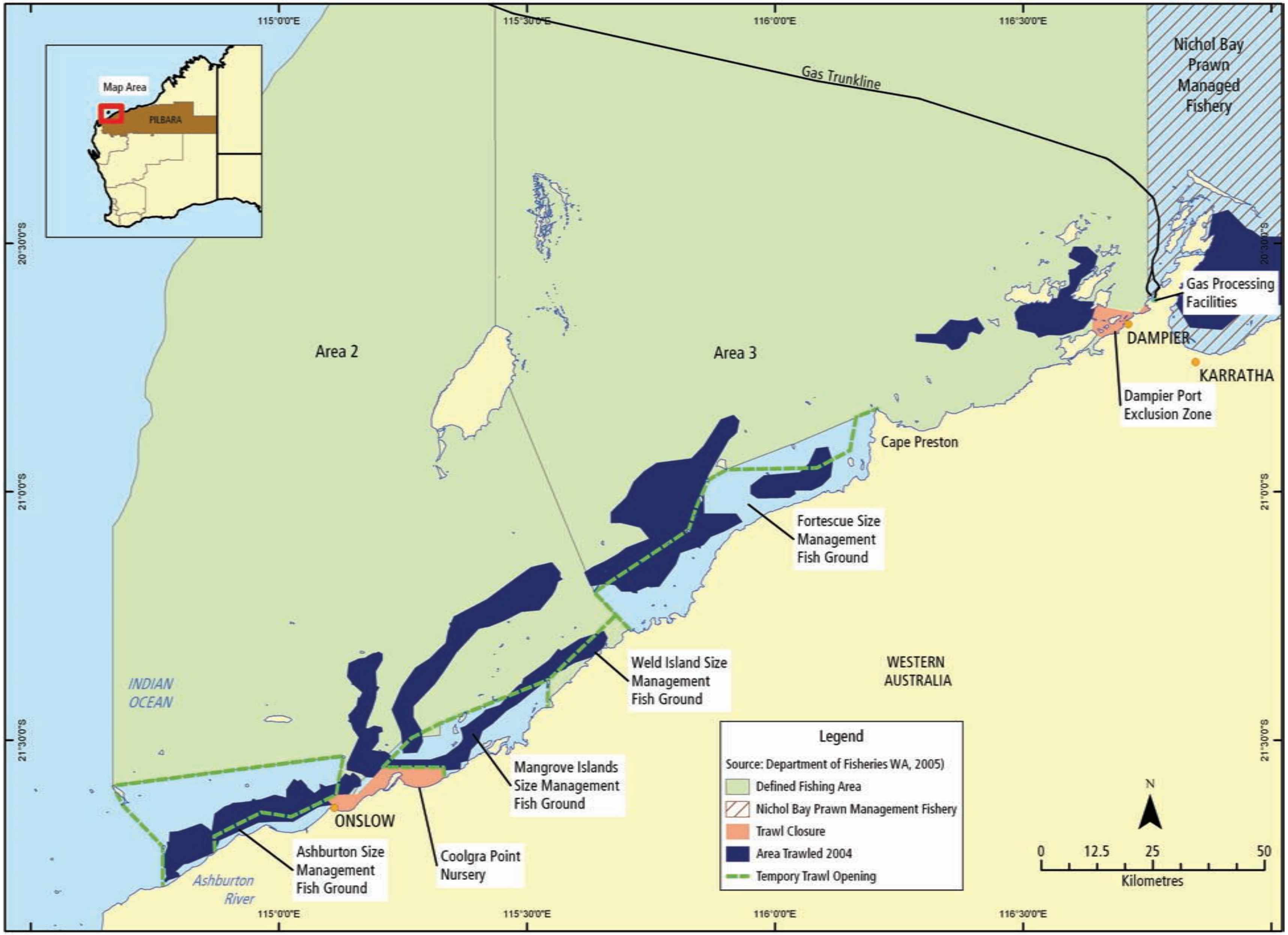
Other smaller scale fisheries in the vicinity of the Development area are:

- the Marine Aquarium Managed Fishery – 13 licenses, some operating within the Dampier Archipelago area
- the Western Australian Specimen Shell Managed Fishery – 32 licenses throughout Western Australia
- the Western Australian Beche de mer Fishery – seven licenses throughout Western Australia.

10.7.4 Recreational Fisheries

Around one third of all Western Australians, or approximately 600 000 people, regularly participate in recreational fishing activities (CALM 2000). In 2003/04 the Pilbara and Kimberley region accounted for 5% of the state's recreational fishing effort (Penn et al. 2005), and in 1999/2000, an estimated 300 tonnes of scalefish was taken recreationally throughout the region from Onslow to Broome, excluding Thevernand Island and Barrow Island charter vessel catches (Williamson et al. in preparation).

Figure 10-12 Onslow Prawn Managed Fishery



The popularity of recreational fishing has grown substantially over recent years in the Pilbara region, with a distinct seasonal peak in winter when significant numbers of metropolitan and interstate tourists travel through the area and visit the Onslow and Dampier Archipelago sections of the coastline. The high tidal range in the area means beach fishing is limited to periods of flood tides and high water (Penn et al. 2005) and consequently much of the angling activity is boat-based. The Pilbara has the highest boat ownership per capita in Australia (CALM 2000).

Licensed fishing tours in the region are also a popular tourism attraction, and at the end of 2003 the Pilbara and Kimberley regions had 97 licensed fishing tour operators providing 2846 recreational fishing tours (Penn et al. 2005).

Several methods of recreational fishing are used throughout the Dampier Archipelago including: line fishing, netting and spear fishing, with line fishermen targeting deepwater large pelagic species as well as trolling for smaller fish within the Archipelago nearshore areas. Creek systems, mangroves, rivers, and beaches also support a variety of recreationally targeted species including blue-lined emperor (*Lethrinus laticaudis*) spangled emperor (*Lethrinus nebulosus*) sweetlip emperor (*Lethrinus miniatus*), red emperor (*Lutjanus sebae*), estuary cod (*Epinephelus coioides*), sea perches such as mangrove jack, trevally species (*Gnathanodon speciosus*, *Caranx ignobilis* and *Caranx sexfasciatus*), sooty grunter, threadfin salmon species (*Eleutheronema tetradactylum*, *Polydactylus macrochir* and *Polydactylus plebius*), and mud and blue manna crabs.

Offshore islands, coral reef systems and continental shelf waters provide species of major recreational interest including sharks, tunas, and billfish, trevally species, mackerel (*Scomberomorus* spp.), tuskfish (*Choerodon* spp.), coral trout (*Plectropomus leopardus*), coronation trout (*Variola louti*) and bar-cheeked coral trout (*Plectropomus maculatus*) (Penn et al. 2005).

Figure 10-13 shows the distribution of recreational fishing in the Dampier Archipelago. Areas offshore containing coral and subtidal rocky reefs are targeted while artificial habitat created by existing gas pipelines is also popular.

Recreational fishing is managed by the spatial restrictions that have been proposed on recreational fishing in the Dampier Archipelago Marine Park and Cape Preston Marine Management Area Indicative Management Plan.

10.7.5 Pearling and Aquaculture

Several land-based aquaculture sites exist in the vicinity of the Pluto LNG Development. There are currently no active pearling leases in the Dampier Archipelago. **Figure 10-14** shows aquaculture activities in the Dampier, Karratha and Burrup Peninsula area.

10.8 Infrastructure and Transport Network

The Pilbara region is supported by a modern and efficient infrastructure, with energy, water, transport and communications services.

10.8.1 Air Transport Facilities

There are four major airports in the region, the closest of which is Karratha Airport, 10.5 km (straight line distance) from Site B. Other airports include Port Hedland (international), Paraburdoo and Newman and numerous unsealed strips. Mining communities are serviced by chartered flights on a regular basis.

10.8.2 Ports

The Port of Dampier is managed by the Dampier Port Authority, a state government authority operating under the *Port Authorities Act 1999*. The Port of Dampier is one of Australia's largest ports by tonnage and facilitates the export of iron ore, salt, LNG, liquid petroleum gas and condensate totalling about 89 mtpa. The value of exports is in excess of $7 billion (PDC 2005a), and the Port is of high strategic value to Australia. The Port of Dampier effectively consists of multiple 'ports' within a single port (**Figure 10-3**). Dampier Salt has its own private berth and load-out facilities at Mistaken Island; Hamersley Iron has two private iron ore berths at Parker Point and East Intercourse Island, and a service wharf. Woodside maintains two private LNG, liquid petroleum gas, and condensate wharves at Withnell Bay; and the Dampier Port Authority itself provides a heavy load out facility, barge ramp, and the Dampier Cargo Wharf. In addition, Mermaid Marine provides an extensive range of commercial marine services (PDC 2005a). Other nearby ports are located at Port Walcott (Cape Lambert) and Port Hedland.

10.8.3 Water Supply

Two major water supply schemes currently operate in the Pilbara region. Port Hedland obtains its water supply from bore fields at the Yule and de Grey rivers, while Karratha, Dampier, Roebourne and Wickham receive their water supplies from the Millstream natural aquifer and the Harding Dam.

The Water Corporation, in conjunction with Burrup Fertilisers, has recently commissioned a desalination water supply system to provide cooling water for the Burrup Fertilisers ammonia plant. There are plans to expand this plant into a multi-user system. The Water Corporation requires a capital contribution towards the cost of developing water supply source works and distribution facilities for industry projects that use more than 49 kilolitres of water per day (PDC 2005b).

10.8.4 Communications

Major towns in the Pilbara region have internet connections and access to ISDN, STD, facsimile, telex and data link services.

Figure 10-13 Recreational Fishing in the Dampier Archipelago

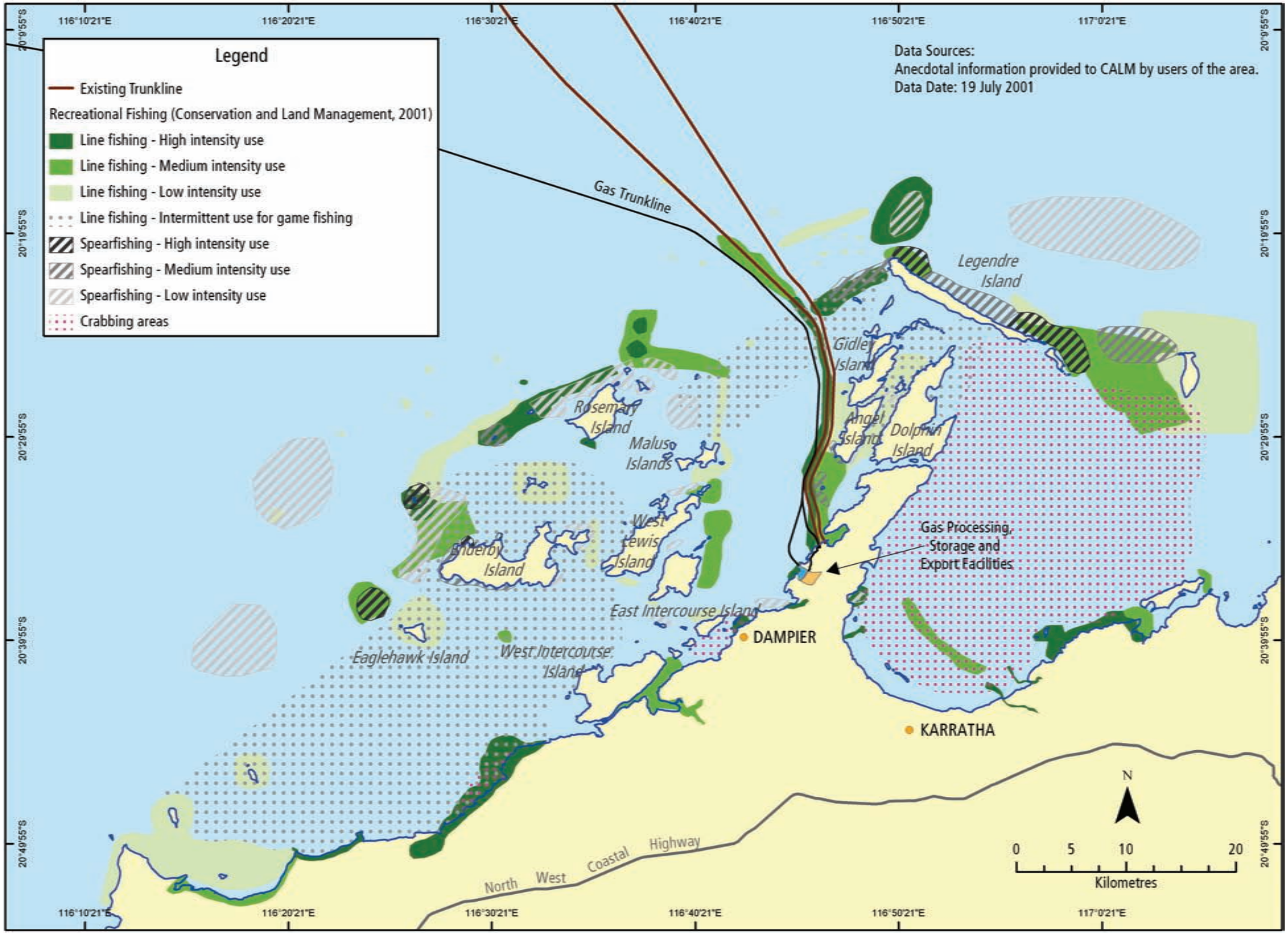
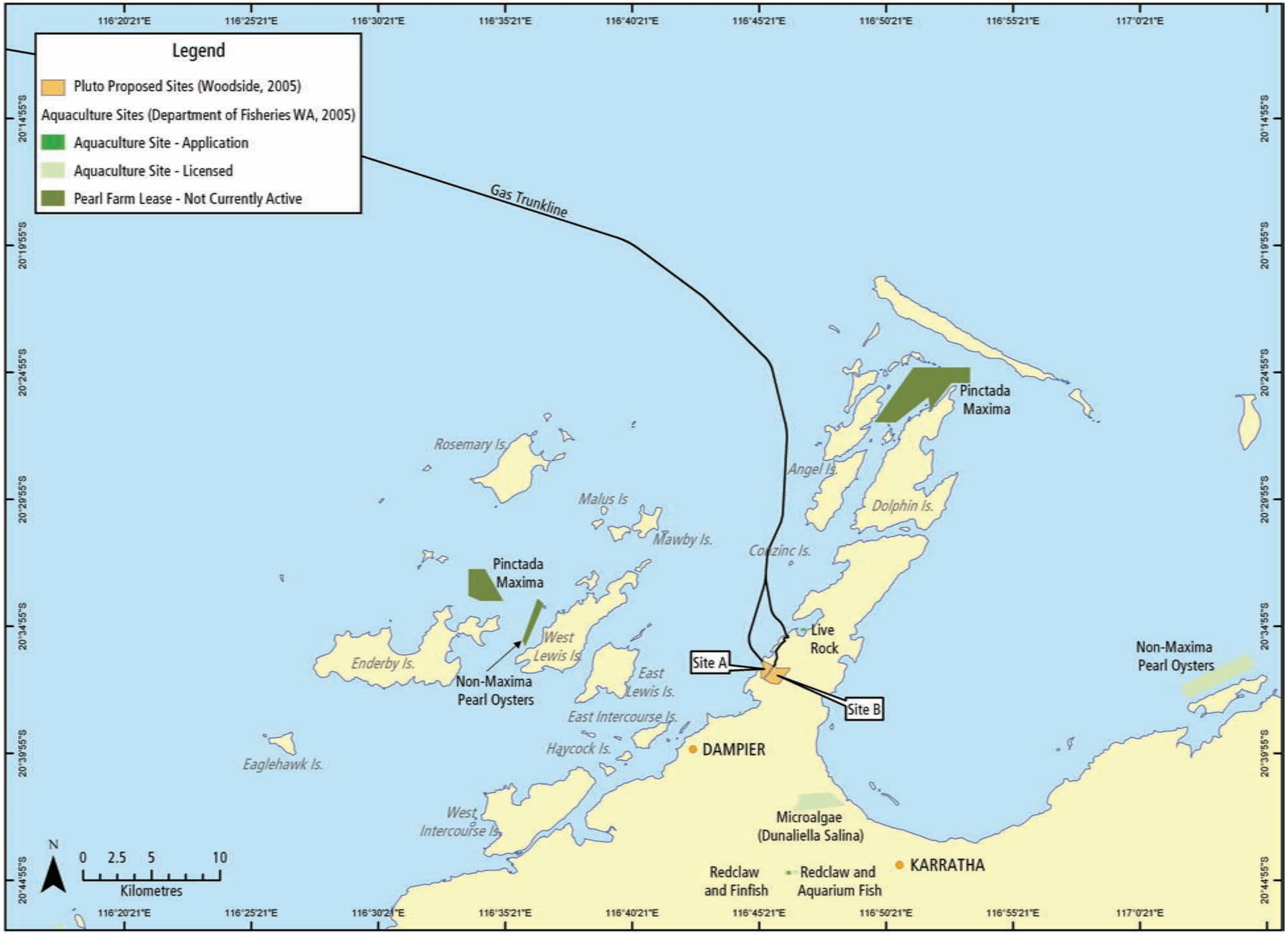


Figure 10-14 Aquaculture Activities in the Karratha, Dampier and Burrup Peninsula Area



10.8.5 Energy

North West Shelf Gas (NWSG) administers contracts for the sale of approximately 550 terajoules of gas per day, including the supply of power stations in the mining areas at Dampier, Cape Lambert, Port Hedland and Newman (PDC 2005a). An interconnected grid combining the resources of Western Power-Pilbara Division and the mining company power stations at Cape Lambert, Dampier, Newman and Port Hedland supplies electricity to many Pilbara communities, while others are serviced by diesel powered stations. NWSG also supplies the privately owned Pilbara to Goldfields gas pipeline, which supplies gas to a number of power stations.

10.8.6 Roads and Traffic

Dampier Road and Burrup Road are the main routes between Karratha and the Burrup Peninsula. Both of these roads are identified as state roads and come under the control of Main Roads WA (MRWA). Burrup Road provides access to Village Road and NWSV Haul Road, the latter providing access to Site B and Site A.

Dampier Road

Dampier Road is a single carriageway two-way road, approximately 26 km long, running between Karratha and Dampier. It is the primary commuter route for the workforce and service traffic that travels between Karratha, Dampier and the Burrup Peninsula industrial sites. The traffic along Dampier Road is largely tidal with the major movement being to and from Burrup in the morning and afternoon peak periods.

Dampier Road, between Burrup Road and Karratha, currently carries in the order of 9000–12 000 vehicles per day. West of Burrup Road, Dampier Road carries approximately 4000 to 4500 vehicles per day. These traffic counts were sourced from MRWA.

Burrup Road

Burrup Road is a two-lane, two-way bitumen surfaced road, providing access between Dampier Road and the Burrup Peninsula. Burrup Road intersects Dampier Road approximately 19 km west of Karratha. Burrup Road carries a high proportion of heavy vehicle traffic between the Port of Dampier and various supply bases, as well as serving as a tourist route to the Burrup Peninsula Conservation Area. The most recent traffic counts for Burrup Road, sourced from MRWA, are summarised in **Table 10-13**.

Local Roads

With the exception of the Burrup Road, which is a state road managed by MRWA, all the roads on the Burrup Peninsula are designated local roads under the care and control of the Shire of Roebourne. These roads include Hearson Cove Road, King Bay Road, the MOF (Material Offloading Facility) Road, Village Road and Cowrie Cove Road.

The most recent traffic counts for these local roads, sourced from the Shire of Roebourne, are summarised in **Table 10-14**.

Current Road Level of Service

Based on the current traffic volumes, the current level of service for the roads that have been described above, and roads on which there may be impacts due to the Pluto LNG Development, is summarised in **Table 10-15**.

The level of service concept describes the quality of traffic service in terms of six levels, designated A to F, with level of service A (LOS A) representing the best operating condition (that is, at or close to free flow), and level of service F (LOS F) the worst (that is, forced flow). More specifically:

- LOS A: Individual drivers are virtually unaffected by others in the traffic stream. Their freedom to select their own desired speed and to manoeuvre in the traffic stream is extremely high, and the general level of comfort and convenience is excellent.
- LOS B: Individual drivers still have reasonable freedom to select their desired speed and to manoeuvre in the traffic stream, although the general level of comfort and convenience is less than at LOS A.
- LOS C: Most drivers are restricted to some extent in their freedom to select their desired speed and to manoeuvre in the traffic stream.
- LOS D: All drivers are severely restricted in their freedom to select their desired speed and to manoeuvre in the traffic stream. Traffic is close to the upper limit of stable flow, the general level of comfort and convenience is poor, and small increases in traffic flow will usually cause operational problems.
- LOS E: Traffic volumes are at, or close to capacity, and drivers have virtually no freedom to select their desired speed or to manoeuvre. Traffic flow is unstable and minor disturbances will result in stop-start conditions.
- LOS F: Flow is forced and the amount of traffic approaching the point under consideration exceeds that which it can handle. Stop-start conditions apply and queuing and delays result.

In general terms a level of service up to C is considered generally satisfactory. Levels of service of D should be avoided if possible, whilst E and F levels of services should be avoided at all times. The current levels of service for the roads presented in **Table 10-15** are considered acceptable.

Table 10-13 Burrup Road Traffic Volume and Composition

Data	North of Dampier Road	South of Withnell Bay Road
Daily traffic volume	2500	2100
AM peak hour volume	370	430
AM peak hour time	6 am to 7 am	6 am to 7 am
PM peak hour volume	350	330
PM peak hour time	4 pm to 5 pm	5 pm to 6 pm
% light vehicle	87.9%	89.6%
% heavy vehicles	11.2%	10%
% long vehicles and road trains	0.9%	0.4%
Date of count	July 2004	March 2003

Note:
- *light vehicles are typically sedans, wagons, 4WDs and same vehicles towing trailers.*
- *heavy vehicles are typically two axle rigid trucks and buses up to four axle rigid trucks.*
- *long vehicles are typically three axle articulated vehicles or a rigid truck towing a trailer and larger.*

Table 10-14 Local Road Traffic Volumes and Composition

Data	Hearson Cove Rd	MOF Road	King Bay Road
Daily traffic volume	100	900	1350
AM peak hour volume	13	73	150
AM peak hour time	11 am to 12 am	10 am to 11 am	6 am to 7 am
PM peak hour volume	12	67	124
PM peak hour time	4 pm to 5 pm	3 pm to 4 pm	4 pm to 5 pm
% light vehicle	95.9%	60.8%	81.4%
% heavy vehicles	41%	36.8%	16%
% long vehicles and road trains	0%	2.4%	2.6%
Date of count	July 2004	September 2004	April 2003

Table 10-15 Current Road Level of Service

Road	Level of Service
NWSV Haul Road north of MOF Road	A
MOF Road west of NWSV Haul Road	A
MOF Road north of King Bay Road	B
King Bay Road east of MOF Road	C
Burrup Road south of King Bay Road	C
Burrup Road north of King Bay Road	D

Note 1: The process of calculation of the level of service for the various roads involved cross referencing of the recorded traffic volumes and the current proportion of heavy vehicles with Table 3.9 of the Guide to Traffic Engineering Practice, Part 2, Roadway Capacity, Austroads, 1999.

10.9 Marine Traffic

Figure 10-15 shows plots from the Australian Ship Reporting Records for 1999–2004, in which shipmasters provide position reports on a 24-hour basis. Reporting is mandatory for certain ships and most other commercial ships participate voluntarily. Several significant shipping routes exist to the east of the Pluto LNG Development, heading north from the Port of Dampier. A relatively low number of vessels are observed within a shipping route heading north-east in the vicinity of the Pluto gas field.

Information provided by the Australian Maritime Safety Association (L Murray [AMSA, Manager GIS] pers. comm., 12 January 2006), indicates significant designated shipping routes, orientated east-west in the vicinity of the offshore gas trunkline.

The Port of Dampier is one of Australia's largest ports by tonnage (refer to **Section 10.8.2**), and the majority of ships move from industrial ports within the Port of Dampier, including Mistaken Island (Dampier Salt), Parker Point and East Intercourse Island (Hamersley Iron) and Withnell Bay (Woodside) through Mermaid Sound shipping lanes and into open waters.

In 2004/2005 there were 2105 trade vessel arrivals and further 564 other vessel arrivals for a total of 2669 arrivals at the Port of Dampier (Worley Parsons 2005). According to comment from the Dampier Port Authority Harbourmaster, most trade vessels, excluding only some general cargo ships, operate through Mermaid Sound rather than Mermaid Strait. It can therefore be assumed that approximately 2000 vessels travelled through Mermaid Sound in the 2004/2005 financial year (Worley Parsons 2005).

No published information is available on the number of vessel movements through Mermaid Strait. However, according to the Dampier Port Authority Harbourmaster, vessel traffic in the Mermaid Strait averages 150 movements per month with a typical vessel size range of 150 to 5000 tonnes (Worley Parsons 2005). The number of movements is expected to double over the next 18 months (V Justice, pers. comm. 2005). Primarily resource trade vessels pass through Mermaid Sound while traffic through Mermaid Strait is more likely to be offshore oil and gas support, recreational, fishing or general cargo related (Worley Parsons 2005).

Given the distance from shore and depth of water, little or no recreational boating is expected in the area of the Pluto gas field or along much of the gas trunkline route. Recreational boating within the Dampier Archipelago is very popular and is discussed in **Section 10.10**.

10.10 Tourism and Recreation

The Pilbara region is becoming an increasingly popular visitor destination for Australian and international tourists. Average annual visitor numbers for 2003–2004 were 274 500 and 29 300 for domestic and international tourists respectively, with an expected annual increase in international visitors of 5.8% to 2014 (TWA 2005). Domestic visitors alone contributed an estimated $145 million per annum to the regional economy over 2003–2004. Notwithstanding the high profile of recreational tourism, the most commonly cited reason for visiting the Pilbara region is for business purposes, and in 2003 and 2004, 45% of visitor nights in the region were for business purposes, 33% stayed overnight for the purpose of leisure, while 13% were visiting friends and relatives (TWA 2005).

Major tourist attractions in the western Pilbara region include the gorge at Karijini National Park, the oasis at Millstream and the historic settlements of Marble Bar and Cossack. In Karratha, the Jaburara Heritage Trail, a 3.5 km walk around the town detailing Aboriginal heritage is a popular visitor attraction, and includes stops at Aboriginal carvings, old quarries and shell middens.

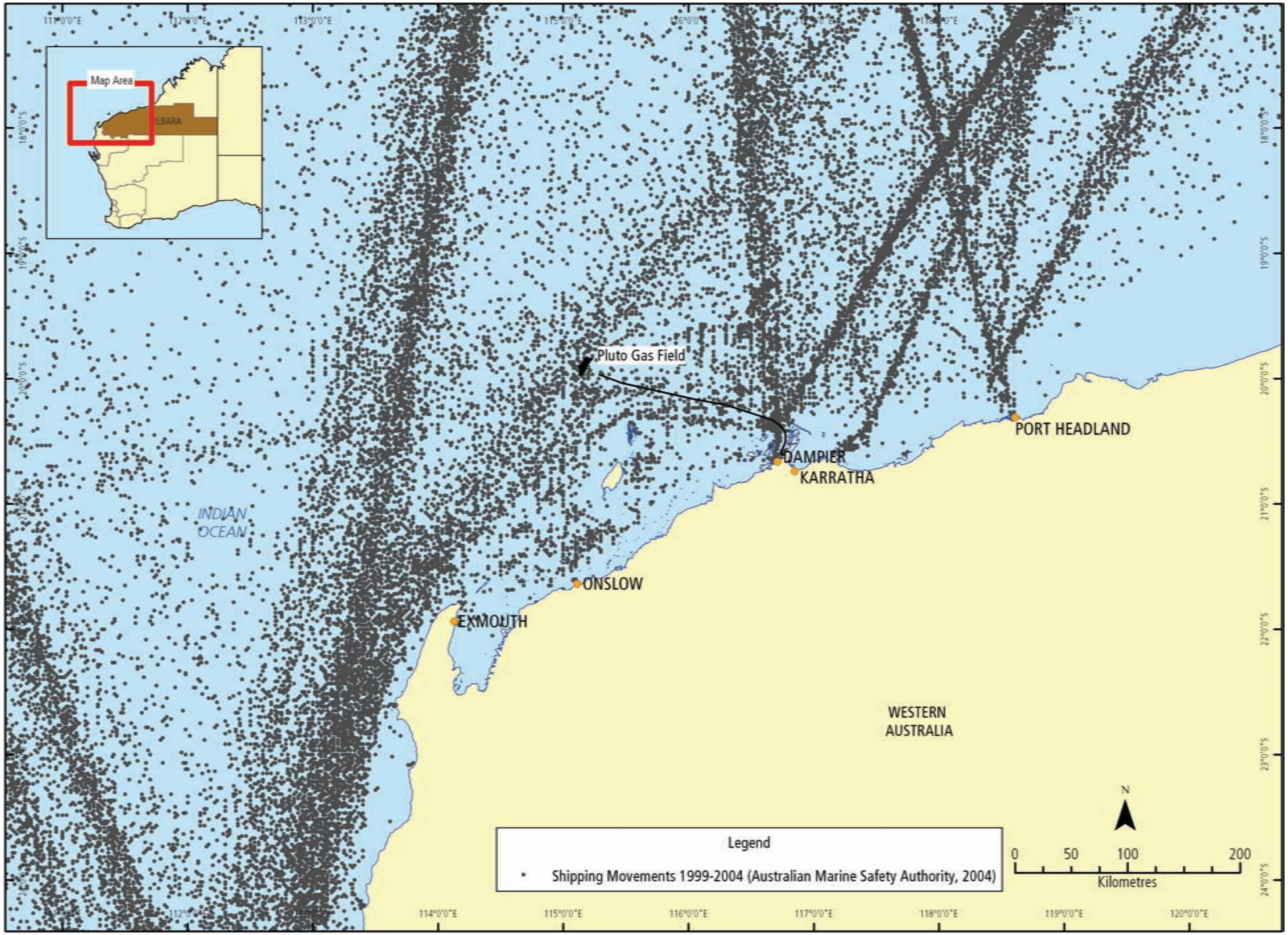
A recent and ongoing initiative by the Western Australian Tourism Commission is industry-related tourism, with tourists encouraged to visit several of the industries in the area, which have viewing stands and other tourist-related facilities. The NWSV Karratha Gas Plant has already generated considerable tourism interest and is a major attraction in Karratha and the Burrup Peninsula. It is also possible to visit and inspect the Dampier Port facilities. It is envisaged that Dampier and Karratha will begin to play an important role in the tourism industry, acting as gateways to the Burrup Peninsula and to the Dampier Archipelago.

The region's coastline, which includes the islands of the Dampier Archipelago, is also popular for aquatic activities, and several protected coves and bays located on the Burrup Peninsula are used for recreational purposes by the local community. Activities undertaken include fishing as well as spear fishing, swimming, diving and boating. Hearson Cove, Withnell Bay, Cowrie Cove, Watering Cove, Conzinc Bay and King Bay are the most popular locations. Areas of the Dampier Archipelago within close proximity of recreational boat launching access are used extensively for recreational boating. Small dinghies can be launched from sheltered shorelines wherever there is vehicle access, and several undeveloped launching sites are used regularly at locations including Withnell Bay, King Bay Fishing Club and Hearson Cove. Several sealed boat ramps exist in Hampton harbour at Dampier.

Hearson Cove beach is a popular social venue used for swimming, picnics, parties and barbeques, and is also a popular destination for school excursions. Several petroglyphs are located in the area, which are also tourist attractions.

South of Holden Point, bordering Site A, there is a sandy bay which is used for recreational purposes. As the existing haul road to the beach is fenced, the only access to this beach is currently by boat. Popular areas for recreational activities are shown in **Figure 10-16**.

Figure 10-15 Shipping Activity on the NWS



10.11 Visual Amenity and Landscape Character

Given the absence of established assessment methods in Australia at present; the assessment process for both landscape and visual impacts was undertaken in accordance with the Guidelines for Landscape and Visual Impact Assessment (2002), published by the UK Landscape Institute and the UK Institute of Environmental Management and Assessment.

The assessment has been based on desk-top study and field survey. Photomontages were created to further augment the process and to assist readers in visualising the proposed development.

10.11.1 Burrup Peninsula Land Use Plan and Management Strategy, September 1996

The diversity of the Burrup Peninsula was recognised in the Land Use and Management Strategy with the sub-division of the Peninsula into separate management zones with differing landscape character descriptions. This Management Strategy was updated by the proposed Burrup Peninsula Conservation Reserve Management Plan that was published as a draft for consultation in mid-2006.

In the original management plan released in 1996, Site A and Site B lie within areas denoted as industrial zones; Site A and Site B being situated in Zone C–Burrup West.

The industrial area definition of the Burrup Peninsula in both strategies is largely concentrated at the western extent of the Peninsula with protrusions of industrial land into the centre of the Peninsula between Hearson Cove and King Bay and immediately south of Mount Wongama in the centre of the Peninsula.

The remainder of the Burrup Peninsula is designated as Conservation, Heritage and Recreation Area with two zones of note in close proximity to Site A. Zone 2–Central Burrup is located immediately east and north of Site E and 0.5 km east of Site A. Zone 3–Southern Burrup is located at the southern extent of the Peninsula, approximately 1.5 km south of Site B.

10.11.2 Proposed Burrup Peninsula Conservation Reserve Management Plan, 2006

The proposed management plan outlines the Department of Environment and Conservation's intention to provide formal protection to parts of the Burrup Peninsula under the *Conservation and Land Management Act 1984*.

In relation to visual impacts, the proposed strategy states the following:

> for many people, the industrial aspect (sic. of the Burrup Peninsula) will detract from natural landscape values. Siting facilities to screen industry from the viewshed will be attempted wherever possible.

The overarching objective of this proposed management plan in relation to landscape and visual impacts is to 'minimise adverse impacts on the landscapes of the proposed reserve.'

Applicable strategies relating to industrial development include:

- Assess the landscape impacts of all planned works visible from inside the proposed reserve and seek to minimise any unacceptable visual impact by participating in processes relating to the landscape and environmental impacts of industrial development on the adjacent industrial lands.
- Consult with state and industry officials about the aesthetic and design standards for industrial lands.

10.11.3 Landscape Character of the Study Area

The following landscape character types were identified within the southern extent of the Burrup Peninsula:

- industrial complexes (south and north of Site B and Site A)
- tidal flats, inlet and saline flats (within Site A)
- high scree slopes and rock outcrops (within and adjacent to Site A and Site B)
- grassland steppes (within Site B and Site A)
- valleys and incised drainage lines (within Site B and Site A).

Table 10-16 below outlines the value of the landscape character types and their capacity to tolerate change.

10.11.4 Visual Baseline

Residential Properties (High Sensitivity)

There are no residential properties within 2 km of Site B and Site A, or the proposed onshore gas trunkline. The nearest settlement is the town of Dampier, approximately 7.6 km (straight-line distance) south-west of Site A and 6 km (straight-line distance) from Site B. The larger town of Karratha, the administrative centre of the Shire of Roebourne, is located 18 km (straight-line distance) to the south-east of Site A and approximately 15.5 km (straight-line distance) to the south-east of Site B. Given the distance and intervening topography between the proposed development sites and the township, residential properties are not considered to be a significant receptor in this case and as such, they are not addressed further.

Business and Industrial Premises (Medium-low Sensitivity)

The southerly extent of the Burrup Peninsula and a small section extending northwards from King Bay to Withnell Bay is zoned as strategic industrial land. In view of this zoning, several heavy industrial installations have been constructed within the zoned land, as depicted in **Figure 10-3**, including the following:

- Dampier Port/Western Stevedores
- Karratha Gas Plant
- Burrup Fertilisers Ammonia Plant
- Dampier Salt Operations
- Hamersley Iron Dampier Port Facilities
- Mermaid Marine Facility/Woodside Supply Base
- Ancillary Supply Companies.

Road Network (Low Sensitivity)

The southern extent of the Burrup Peninsula is connected by a series of roads that pass in close proximity to the proposed development sites. The roads that are described in the landscape and visual impact assessment include the following:

- Village Road
- Burrup Road
- King Bay Road
- MOF Road
- Hearson Cove Access Road.

Recreational Rights of Way and Facilities (Medium-High Sensitivity)

There are several recreational rights of way and facilities, four wheel drive tracks and beaches in the southern extent of Burrup Peninsula. Given the small distances between Burrup Peninsula and the townships of Dampier and Karratha and the natural and cultural value of this area these facilities are regularly used. The features include:

- Hearson Cove four wheel drive tracks
- four wheel drive track between Village Road and Cowrie Cove
- Hearson Cove
- Holden Beach (access by boat only)
- Mermaid Sound/Nickol Bay.

10.12 Military Zones

The Pluto gas field falls within the Western Australian Exercise Area (WAXA). The area of the WAXA within which the Pluto gas field falls is used as a military flying area and is shown in **Figure 10-17**.

Table 10-16 Landscape Character and Types with Capacity to Tolerate Change

Character Area	Landscape Type	Value	Quality	Contribution to Landscape Setting	Substitution	Ability to Accept Change
Industrial Complexes	Industrial	Low	Low	Low	High	High
Tidal flats, inlet and saline flats	Natural	High	High	High	Low	Low
High scree slopes and rock outcrops	Natural	High	High	High	Low	Low
Valleys and incised drainage lines	Natural	High	High	High	Low	Low
Grassland steppe	Natural	High	High	High	Low	Low

Source: SKM 2006d

Figure 10-16 Recreational Activities on the Burrup Peninsula

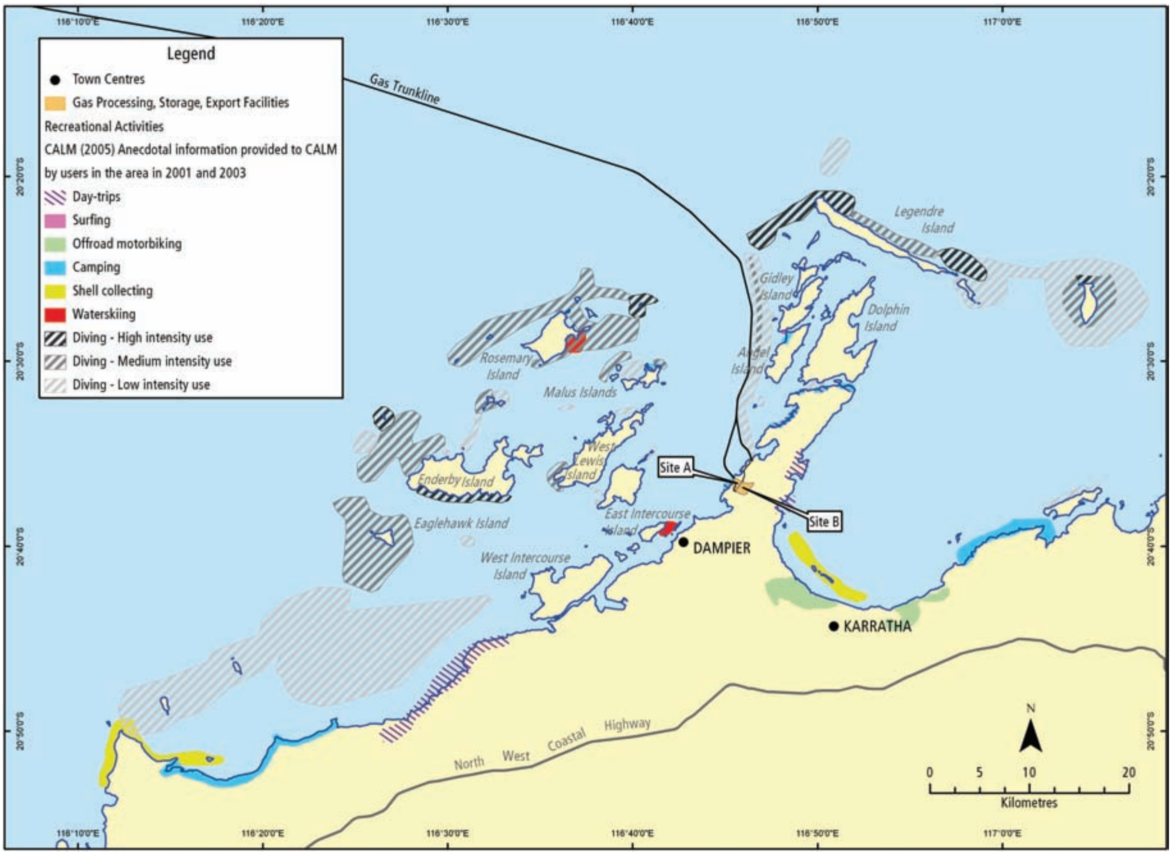
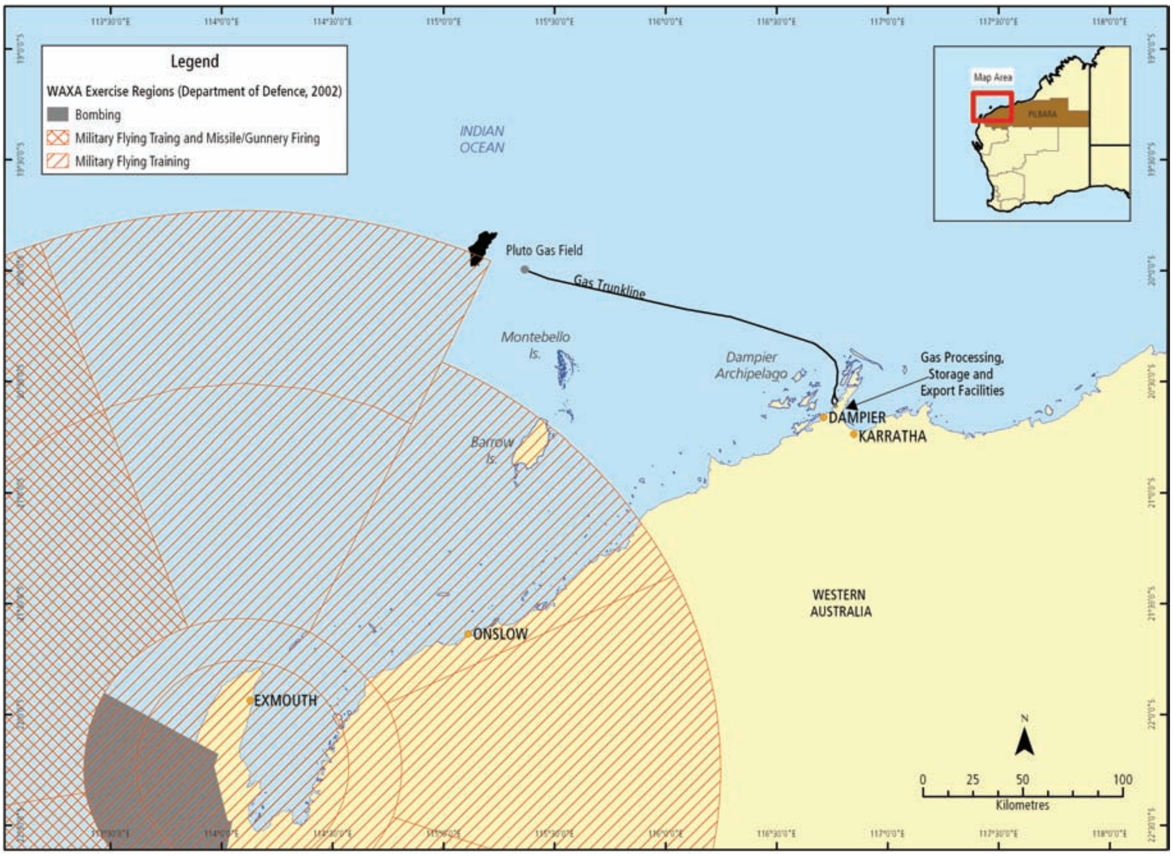


Figure 10-17 Military Zones in the Vicinity of the Pluto LNG Development



Social and Economic Impacts and Management 11

11.1 Summary of Impacts

This section of the Draft PER identifies the potential social and economic impacts from the proposed Pluto LNG Development and associated preventative and management strategies that will be implemented to reduce impacts to an acceptable level.

Activities associated with the Development have been assessed through a comprehensive impact assessment process which has been verified using the Woodside corporate risk assessment tool described in **Section 7.2**. This process allows potential environmental impacts to be systematically identified and considered on the basis of potential risk to the environment. This subsequently assists in prioritising development of management measures to achieve an overall acceptable level of risk to the environment.

It should be recognised that a formal risk assessment of environmental issues is only one of the tools employed to identify and rank the key environmental impacts of the Pluto LNG Development. The value of the risk assessment is as a high-level screening tool, to identify the impacts that require detailed assessment. The results of the risk assessment should not be interpreted in isolation from the broader assessment process described within this Draft PER.

The impact assessment concluded that both positive and negative impacts will generated during the life of the Development. Some of the key positive impacts will include:

- peak direct construction employment of up to 3000 people, with up to 200 long-term jobs during operations
- opportunities for Indigenous participation in business development and training programmes
- contribution of $17.6 million to Australia's Gross Domestic Product and $29 million to Western Australia's Gross State Product, based on a two train development
- increased opportunity for local economic activity
- creation of training and business opportunities.

Priority has been given to development of management measures to address the following potential social and economic impacts:

- Disturbance to Aboriginal heritage sites where these sites cannot be avoided (**Section 11.4**).
- Increased demand for accommodation (**Section 11.2**).
- Increased pressure on key services including health, childcare, education and training (**Section 11.2**).
- Temporary road closures during transport of modular components during construction phase (**Section 11.9**).
- Increased volumes of traffic primarily due to workforce travelling to site during the construction phase (**Section 11.9**).
- Permanent and temporary spatial restrictions, and navigational hazards to marine traffic in Mermaid Sound (**Section 11.10**).
- Visual impacts from the construction and operation of the plant facilities to existing user groups (**Section 11.12**).
- Some reduction in fishing grounds due to exclusion zones/ risk of snagging on marine infrastructure (**Section 11.8**).
- Disturbance to recreational fisheries and recreational values within Mermaid Sound during dredging and dredge spoil disposal activities (**Section 11.11**).

To address higher priority impacts a number of key mitigation and management measures have been developed within a series of framework EMPs which will ensure that all impacts are minimised to acceptable levels. Key mitigation and management measures include:

- Disturbance to any Aboriginal heritage sites will be in accordance with Section 18 of the Aboriginal Heritage Act.
- Aboriginal heritage sites will be left in-situ wherever practicable.
- The width of offshore trunkline corridor will be limited to reduce potential impacts to fish habitat, feeding and spawning areas.
- Exclusion zones around platform and subsea installations will be gazetted and marked on admiralty charts to reduce likelihood of collisions with the offshore platform and/or snagging of trawl gear on subsea installations.
- An exclusion zone will be established around the export jetty.
- During the Front End Engineering and Design phase the digital terrain elevation model will be used again to simulate the 'as built' design specifications for facilities at Site A and Site B.

Woodside will work with the local community as well as the local, state and Commonwealth governments to mitigate and manage any negative impacts, and maximise the opportunities presented by positive impacts.

11.2 Social Impact Management

Purpose and Objective

Woodside will conduct a social impact management process to, as far as possible, identify and manage key social impacts associated with the Pluto LNG Development. The purpose of developing a Social Impact Management Plan is to:

- identify the nature and magnitude of any social impacts (both positive and negative)
- contribute to a better understanding of the Development by those potentially affected and those with responsibilities towards potentially affected groups and individuals
- facilitate the expression of views, concerns and aspirations about the Development by those potentially affected
- assist Woodside and potentially affected people, communities and organisations, to plan activities associated with the Development in such a way as to optimise the potential positive impacts and mitigate any potential adverse impacts on affected communities.

The Shire of Roebourne has seen a number of projects proposed or developed in recent years. Given that significant research has already been undertaken, Woodside is using existing baseline data and studies to understand and identify the likely social impacts on the area. This baseline will be tested with relevant local stakeholders.

Consultation Methodology

Consultation in relation to community needs, aspirations and concerns will be conducted with an aim to:

- provide the local community with information about the Pluto LNG Development and encourage them to participate and provide relevant feedback in regards to both the potential impacts and the management of those impacts
- seek suggestions and advice from members of relevant organisations regarding the development of strategies, or opportunities for addressing concerns and realising opportunities.

Interviews, workshops and/or surveys will be conducted with relevant stakeholders in the appropriate fields including health, education, housing and infrastructure and other service providers (such as Centrelink) and local and regional Indigenous organisations.

Potential Impacts

The identification and assessment of potential impacts will be determined by the use of the following methods:

- description of the potential impact and timing
- consultation with stakeholders likely to be affected
- assessment of the potential impact, including significance and level of impact (positive or negative).

Based on initial reviews, consultation and desktop studies, initial social impacts that have been identified include (but are not limited to) the following broad categories:

- housing and land availability, including design and location
- employment, education and training
- workforce management
- local, state and national economic activity
- community development and essential service availability.

Preventative and Management Measures

Social impact risks will be determined and management strategies finalised in the Social Impact Management Plan. Suitable strategies will be developed and implemented that either mitigate or enhance potential social impacts that affect the community. This may include identification of opportunities which will contribute to developing sustainable communities. Consultation with key local stakeholders will ensure mitigation and enhancement strategies are accepted in the community and culturally and contextually appropriate.

Woodside engaged consultant experts in the focus areas of the implications of fly-in/fly-out workers, housing issues and vocational training. The results of this work will provide a reference for in-depth strategy development and opportunity for identification in these key areas.

Review and monitoring will be an essential stage in the development and realisation of a successful Social Impact Management Plan. Woodside will endeavour to allocate responsibility for the potential impact and identify mechanisms to monitor the effectiveness of mitigation or enhancement strategies. A schedule identifying key milestones for the development of the Social Impact Management Plan is provided in **Table 11-1**.

11.3 Economic Environment

The economic impact of the Pluto LNG Development has been estimated using the MMRF-Green model operated by the Centre of Policy Studies at Monash University and analysed by Insight Economics. The results presented here are based on the best available data at the time of this Draft PER and are presented relative to the 'business as usual' MMRF-Green Base Case. The Base Case represents the notional 'business as usual' MMRF-Green simulation where no Pluto LNG Development is assumed to occur. All major projects that have been committed at the time of the simulation are included in the MMRF-Green Base Case. The following analysis is based on two LNG trains.

Table 11-1 Schedule and Milestones for the Development of the Social Impact Management Plan

Milestone/ Schedule	Activity/ Task
January 2006	Developed terms of reference, methodology, definition of terms and scope of work
February 2006	Commenced research including gathering baseline information, project data, relevant academic and consultant resources
March 2006	Appoint consultants to do further research into focus areas – housing, fly-in fly-out and training
April–June 2006	Community consultation on the identification and assessment of the potential social impacts
July–October 2006	Finalisation of Focus Reports and consultation with key stakeholders on management strategies
November–December 2006	Drafting and Review of the Social Impact Management Plan
Early 2007	Finalisation of the Social Impact Management Plan

The economic modelling shows that there are significant benefits for the local, regional and national community that would flow from the Pluto LNG Development, both during the construction period and the operational phase. The Pluto LNG Development will represent a major increase in investment, which would have significant flow on, 'multiplier' effects for the rest of the economy. Businesses supplying inputs into the Pluto LNG Development would be expected to expand, increasing their levels of investment and labour, too. This would be expected to increase employment and wages, which would in turn increase Australian household income. As economic activity increases, so will government revenues. Thus the Development would be expected to result in strong growth in other industries as the multiplier effect drives greater activity in Western Australia's economy.

While the Pluto LNG Development scope will not be defined until the development takes Final Investment Decision, modelling indicates that it will boost Gross Domestic Product (the national economy) over the life of the project by up to $17.6 billion in net present value terms (NPV5%, 2007-2035). All cash flows were estimated in real $2005 terms and have been discounted back to present value terms at a conservative social discount rate of five per cent. The modelling also shows that consumer welfare, measured by private consumption, would be expected to be $12.2 billion greater in NPV5%, 2007-2035 terms than in the MMRF-Green Base Case.

Commonwealth revenue from company and income tax, GST and royalties is expected to be boosted by up to $5.5 billion. State and local government revenue would be expected to increase by up to $445 million in NPV5%, 2007-2035 terms.

It is expected that over 55% of the total Pluto LNG Development direct expenditure will go to Australian produced goods and services and around 90% of all operational expenditure is expected to be sourced in Australia. Woodside's profits will be distributed to its shareholders, the majority of which are Australian.

There are also benefits flowing from the Pluto LNG Development that are specific to Western Australia. These benefits include the creation of training and business opportunities, and substantial employment and economic growth in Western Australia.

Woodside expects that approximately 200 direct jobs would be created during the operational phase. Woodside plans to source the workforce from Western Australia where possible. The majority of these jobs are skilled, which would provide a key pathway to allow employees, including local Indigenous employees, to gain vital 'on-the-job' experience.

Due to the multiplier effects of the Development, the modelling shows that more than 4000 additional jobs would be created on average in Western Australia from 2007 to 2023 as a result of the Pluto LNG Development. More than 3700 jobs would be created in the State from 2024 to 2035.

The Pluto LNG Development will generate benefits for the Pilbara region in particular. The flow-on economic activity is expected to generate up to 3223 additional jobs each year on average in the Pilbara region during the construction phase. The MMRF-Green modelling also projects an increase in the Gross Regional Product of the Pilbara region of up to $24.6 billion in NPV5%, 2007-2035 terms.

In addition to the increased employment in Western Australia, the Pluto LNG Development will bring economic benefits to the state due to increased revenue to the government and flow-on economic activity, for example services and increased spending by the construction, operation and maintenance workforces. Woodside has a continuing commitment to source goods and services from the Pilbara or Perth wherever possible, a policy which will have a positive impact on existing businesses in the area.

The key economic impacts of a two-train Pluto LNG Development are summarised in **Table 11-2**.

11.4 Aboriginal Heritage

It has been estimated that the Dampier Archipelago may contain over one million pieces of rock art. In a regional context, Woodside's impact on the overall heritage landscape of the Dampier Archipelago is very minimal; however, the local impacts are greater.

For example, in the context of the regional heritage landscape only a very small fraction of 1% of rock art within the Dampier Archipelago lies within Site A and Site B and even less of this rock art lies within Woodside's proposed Pluto LNG Development disturbance footprint. That is, of the estimated one million pieces of rock art within the Dampier Archipelago, an estimated 150 rock art motifs (single engravings) identified during the archaeological heritage surveys conducted by ACHM lie within the Site A and Site B proposed disturbance footprint.

Locally, the impact is greater with these 150 rock art motifs (that fall within the Site A and Site B disturbance footprint) constituting 5% of the total number of rock art motifs (approximately 3000) that were identified on Site A and Site B during the archaeological heritage survey. Woodside is aiming to retrieve and relocate all of these rock art motifs.

Under Section 18 of the Aboriginal Heritage Act Woodside has submitted notices to develop and operate the Pluto LNG Development within the Burrup Industrial Estate. These notices are submitted to seek approval to disturb Aboriginal heritage sites. In September 2006 the Minister for Indigenous Affairs consented to Woodside using Sites A, E and D subject to certain conditions including Woodside not disturbing heritage sites in the southern portion of Site A. Woodside submitted a notice under Section 18 of the Aboriginal Heritage Act for Site B in late September 2006.

Impacts and Management of Aboriginal Heritage Sites

Woodside has carefully considered the management of and impacts to Aboriginal heritage sites through all phases of the Pluto LNG Development. For example, as discussed in **Section 10.3.3** of this Draft PER, Woodside determined that Site A and Site B may be suitable for development from the point of view of minimising impacts to heritage sites because these areas contain large flat plateau-style upland areas that Woodside knew from the results of previous heritage surveys would likely contain less rock art than would otherwise be evident in deep valley systems and large rocky outcrop areas. As documented below, Woodside estimates that it will leave un-disturbed and in-situ an estimated 95% of rock art motifs (individual engravings) that lie within Site A and Site B. Except for several gully crossing points, this outcome is in part due to Woodside's commitment to locate infrastructure on these plateau areas.

Most importantly Woodside has succeeded in reducing its impacts to the heritage landscape by carefully considering the location of heritage sites when designing the layout of the Development footprint and by consulting with representatives

Table 11-2 Key Economic Impacts of a Two-Train Pluto LNG Development

Milestone/ Schedule	Activity/ Task
Indicator	Value attributable to the Development
Gross Domestic Product	$17.6 billion (NPV)
Gross State Product (WA)	$28.6 billion (NPV)
Gross Regional Product (Pilbara)	$24.6 billion (NPV)
Direct (partial) employment impacts for the Pluto LNG Development	
2007–10 average	1252 jobs (peaking at around 3,500 jobs in 2009)
2011–23 average	193 jobs
2024–35 average	193 jobs
Full employment impacts – WA (includes both direct and indirect)	
2007–10 average	Up to 4990 jobs
2011–23 average	Up to 4041 jobs
2024–35 average	Up to 3741 jobs
Full employment impacts – Pilbara (includes both direct and indirect)	
2007–10 average	Up to 3223 jobs
2011–23 average	Up to 826 jobs
2024–35 average	Up to 287 jobs
Government Revenue	
Commonwealth (including PRRT)	Increase of approximately $8 billion (NPV)
WA State and Local Government	Increase of approximately $445 million (NPV)

Note: NPV_5 calculations based on 2005 real dollars taken over the life of the Development (2005–2035) and discounted at the real rate of 5%

of the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups about how to best minimise impacts to Aboriginal heritage sites. **Figure 11-1a** to **Figure 11-1e** illustrate how Woodside has changed its infrastructure footprint to minimise impacts to heritage sites and take into consideration the advice of representatives from the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo groups.

With reference to Site A the Ngarluma, Yindjibarndi, Yaburarra, Mardudhunera and Wong-Goo-Tt-Oo representatives asked Woodside to reduce the Pluto LNG Development infrastructure footprint on the eastern margin of Site A where a high density of highly significant heritage sites exist. Woodside was also asked to avoid heritage sites in the north-western corner of Site A, immediately adjacent to Holden Point, the beach area and where possible the southern portion of Site A. As illustrated in **Figure 11-1a** to **Figure 11-1e**, Woodside has truncated the Development footprint on the eastern margin of Site A, realigned the infrastructure at Holden Point and has arrived at an outcome where no heritage sites will be impacted in the southern area of the site (**Figure 11-2**). In effect the disturbance footprint has been designed to try and accommodate the wishes of the Indigenous groups of the area and avoid as many heritage sites as practicable.

In relation to Site B Woodside has sought advice from the Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera groups with respect to the design of the infrastructure footprint. At the time of writing this Draft PER the Wong-Goo-Tt-Oo group had not completed their heritage survey report – it is Woodside's intention to seek suggestions from the Wong-Goo-Tt-Oo group regarding the layout of the Site B infrastructure so Woodside can, where practicable, consider and act on those suggestions.

Specifically, the Ngarluma, Yindjibarndi, Yaburarra and Mardudhunera groups asked Woodside to reduce impact to the three valley systems that run through Site B and to preserve two highly significant heritage sites. In accordance with the wishes of these groups Woodside has realigned the Site B infrastructure footprint to minimise impacts to the gully systems, apart from the required crossing points, and has created two 'preservation zones' that will ensure the two heritage sites that the groups want protected will be left un-disturbed and in-situ.

To summarise, Woodside has taken a focussed consultative approach to heritage management where the Indigenous groups of the area have, and will continue to, provide direct advice to Woodside on how the company should minimise its impacts to heritage sites and manage heritage responsibly and respectfully. As illustrated in **Figure 11-1a** to **Figure 11-1e** Woodside has acted on the advice from the Indigenous groups of the area.

Figure 11-1a Initial Site A Design in Relation to Aboriginal Heritage Sites

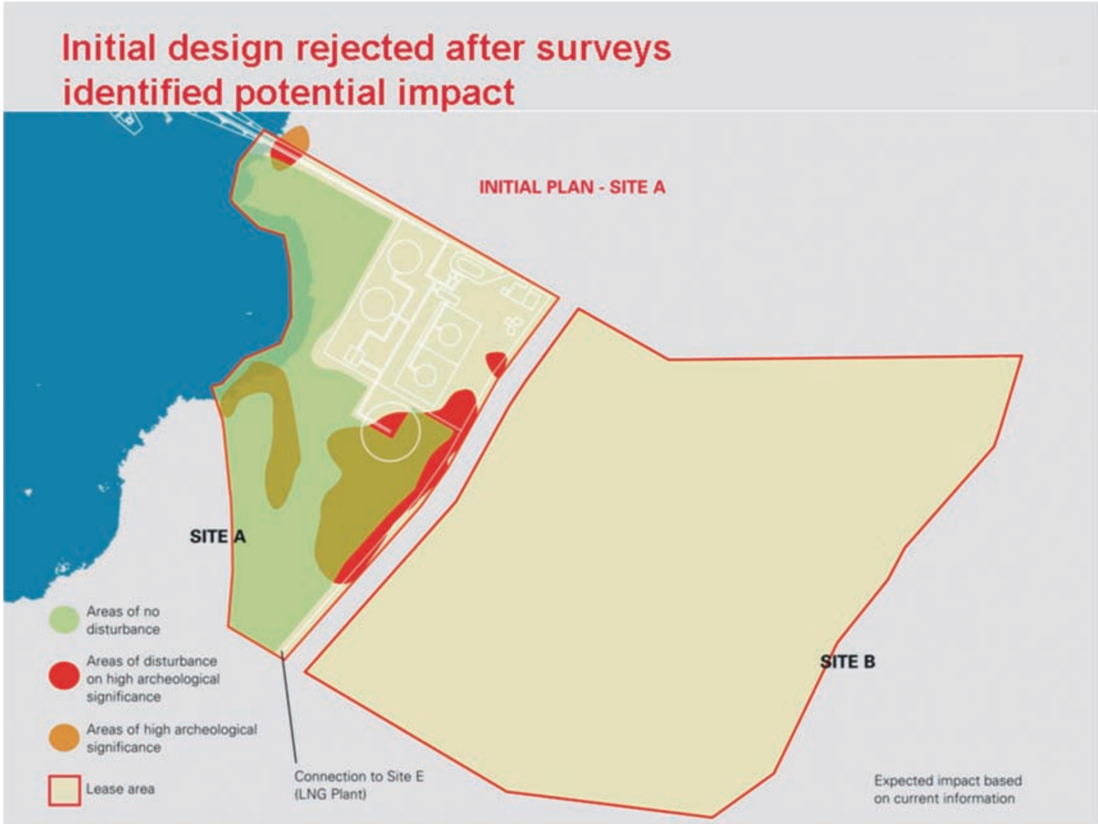


Figure 11-1b Revised Site A Design in Relation to Aboriginal Heritage Sites

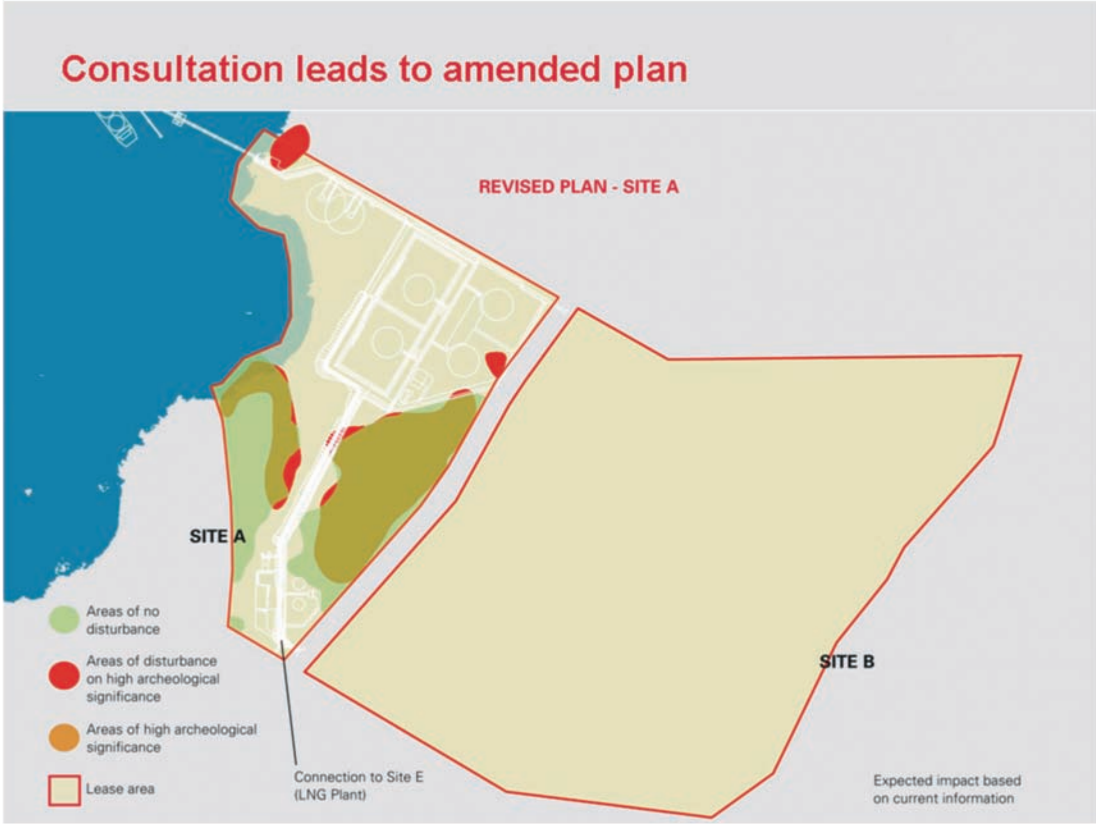


Figure 11-1c Final Site A Design and Initial Site B Design in Relation to Aboriginal Heritage Sites

Figure 11-1d Final Site A Design and Revised Site B Design in Relation to Aboriginal Heritage Sites

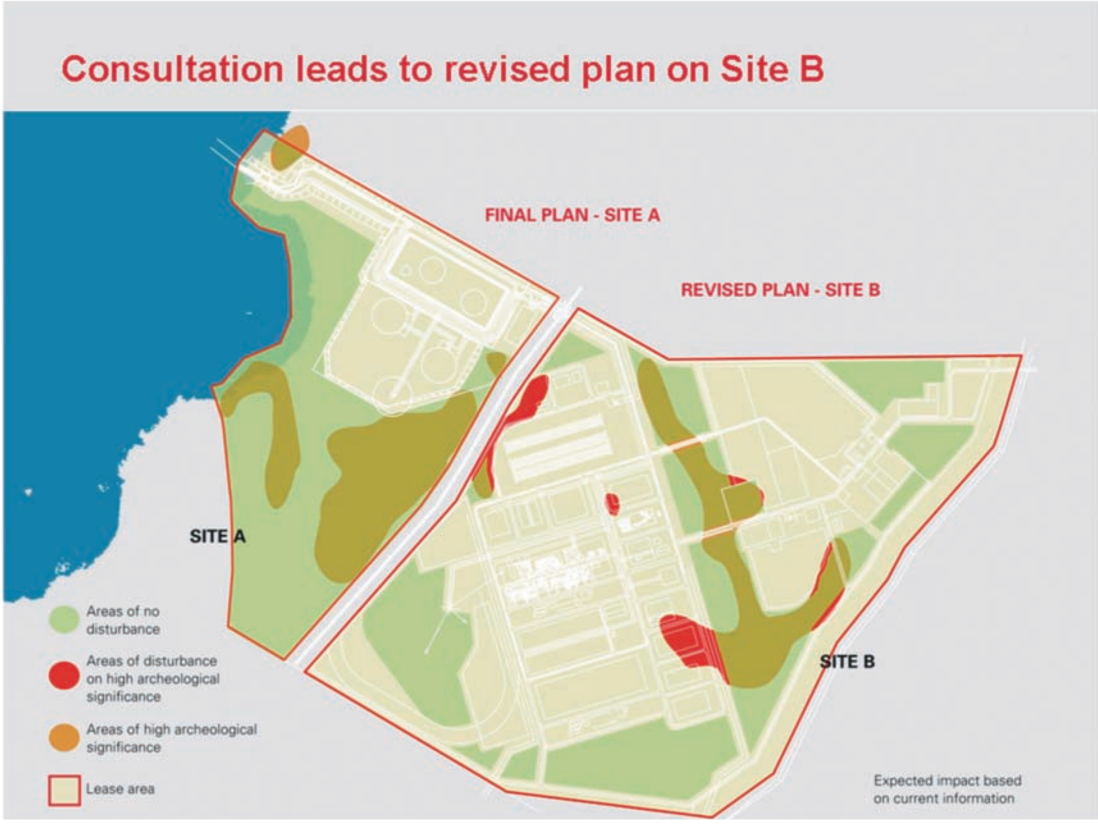
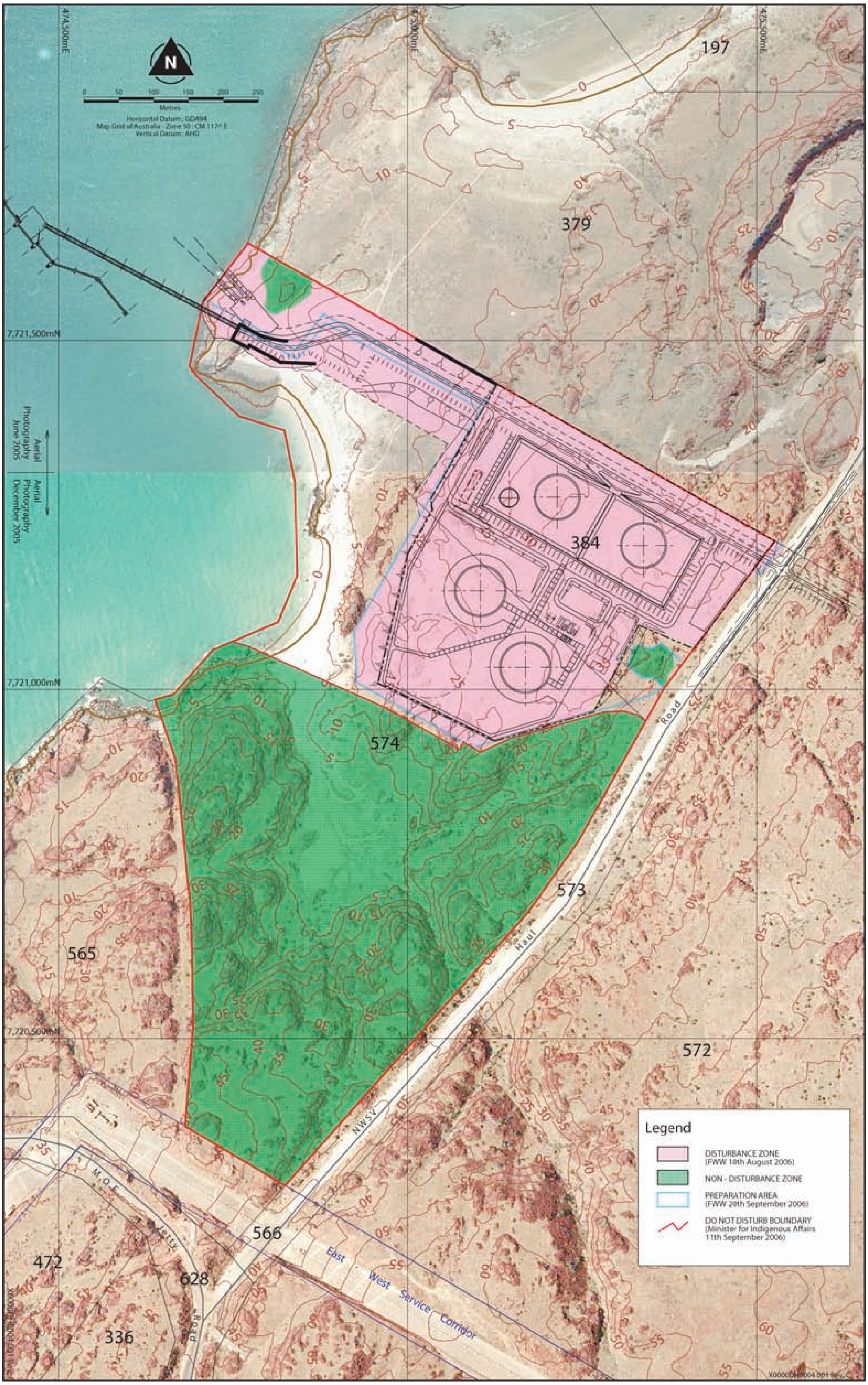


Figure 11-1e Final Site A Design and Proposed Site B Design in Relation to Aboriginal Heritage Sites

Figure 11-2 Site A Non-Disturbance Area



While none of the Indigenous groups of the area are supportive of development on the Burrup Peninsula, through their participation in the heritage surveys and provision of advice on minimising impacts to heritage sites, Woodside is of the understanding that these groups wish to work with the company to influence the approach to heritage management. These Indigenous groups are fully aware of Woodside's proposed activities and the impacts those activities will have on the heritage environment.

This discussion on impacts to Aboriginal heritage sites is split into two sections. First, regional impacts are discussed to provide the reader with an understanding of Woodside's impact on the wider Dampier rock art precinct. Second, local impacts are discussed to provide definition around Woodside's expected impacts to the heritage environment at Site A and Site B where the LNG jetty, storage tanks and gas processing plant will be located.

Figure 11-3 illustrates the area of the Dampier Archipelago rock art precinct in the context of Woodside's proposed development areas at Site A and Site B. The Dampier rock art precinct is estimated by the National Trust of Australia to contain up to one million rock art engravings. Woodside's impact on the heritage environment will be minimal with only a very small fraction of 1% of the rock art of the Dampier Archipelago falling within Site A and Site B and an even smaller percentage of this rock art falling within Woodside's proposed area of disturbance for the Pluto LNG Development.

At a local level, approximately 3000 individual rock art engravings have been found across Site A and Site B and an estimated 150 (5%) of these fall within Woodside's proposed disturbance footprint. Most if not all of these engravings will be retrieved and relocated. In addition 13 artefact scatters, one grinding patch and six man-made structures lie within Woodside's disturbance area.

Woodside has also reduced impacts to highly significant heritage sites with only one heritage site that has been ascribed high archaeological significance lying within the proposed disturbance footprint. In relation to the ethnographic heritage landscape Woodside was advised that the large valley systems within Site B and the southern portion and eastern margin of Site A hold great ethnographic significance to the Indigenous groups of the area. Apart from the valley crossings planned for Site B Woodside will avoid all of these areas.

Woodside will continue to consult with the Indigenous groups of the area in relation to the company's management of the heritage environment. Woodside's Cultural Heritage Management Plan will set the framework for how Woodside will minimise its impacts to the heritage environment and ensure that representatives of the Indigenous groups of the area continue to have an avenue through which to monitor Woodside's heritage management activities, impacts, and influence Woodside's approach to heritage management.

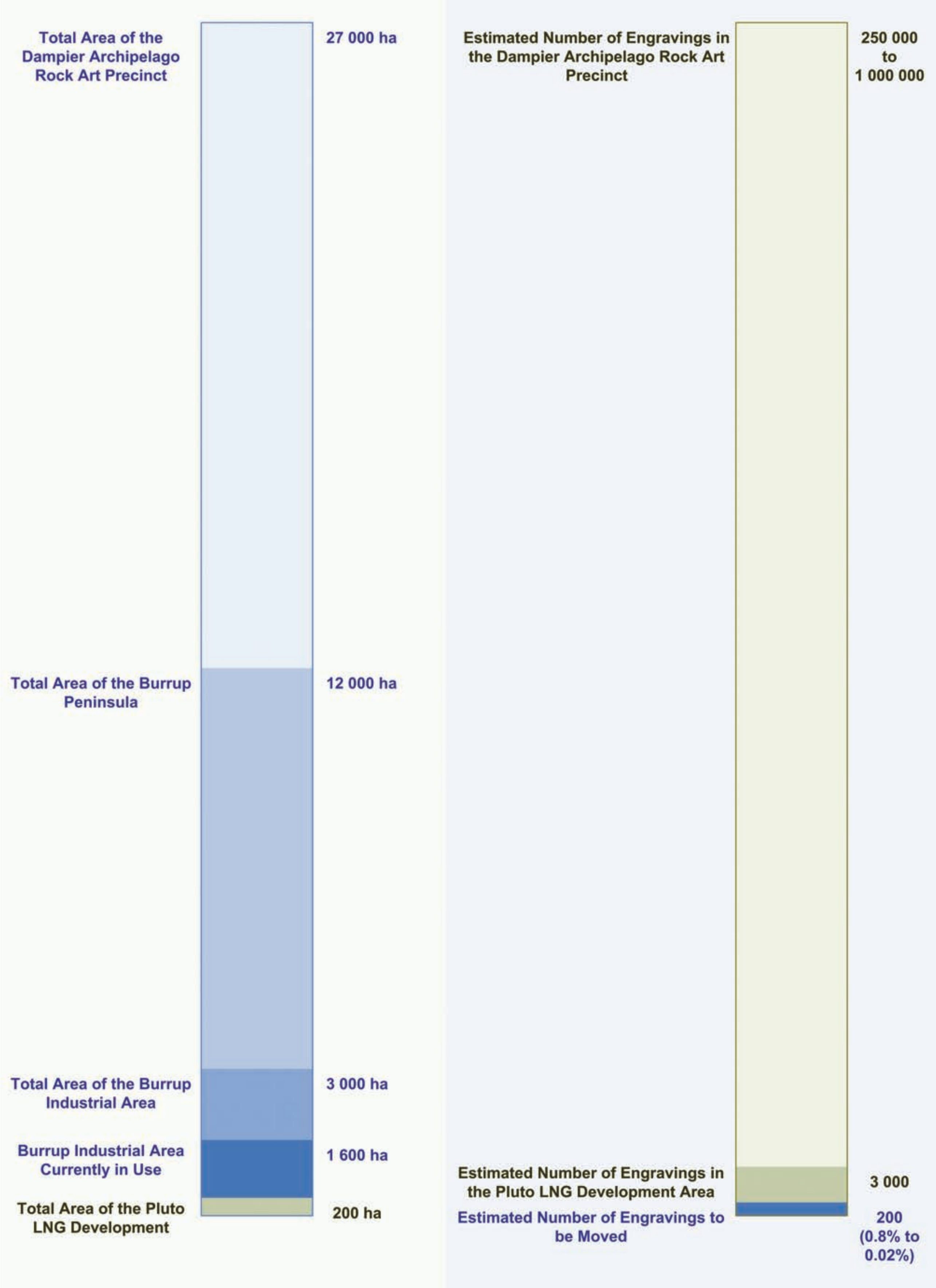
Potential Impacts of Atmospheric Emissions on Rock Art

Rock surfaces are susceptible to natural deterioration from weathering caused by a combination of physical, chemical and biological processes. The ability for human activities to increase the rate of weathering depends on the environment, type and concentration of pollutants to which the object is exposed and the type of rock material.

The presence of heavy industry on the Burrup Peninsula has generated concerns that industrial emissions may lead to an accelerated deterioration of rock art. These concerns centre on the issue of acid deposition which can occur when SO_2 and NO_2 react with water, oxygen and other oxidants in the atmosphere to form acidic compounds. The concerns are that acidic conditions may then alter the natural rate of weathering for rock, making the colour variations and depth of petroglyphs difficult to distinguish from the rest of the rock surface.

Acid deposition takes two forms: dry deposition and wet deposition. Dry deposition is the deposition of gases and particles in the absence of rain while wet deposition occurs when gases and particles are dissolved in rain falling on surfaces (Charola 1998). The deposition rate is a function of a stone's capability to capture or absorb the gases and particles (Livingston 1997 in Charola 1998). Acids that are important in terms of stone damage are carbonic acid, sulfurous acid, sulfuric acid and nitric acid (Ross et al. 1989). Research has shown that sulfurous acid is the main contributor to rock damage (Charola 1998). Other mechanisms involved in air pollution damage to stone are aqueous dissolution of calcium carbonate (limestone and marble) and particle build-up on stone surfaces (Irving 1991; Ross et al. 1989; Bravo et al. 2006).

Figure 11-3 Regional Impacts of the Pluto LNG Development on Aboriginal Heritage Sites



The effects of acid deposition on stone monuments have been researched extensively in Europe and North America (Charola 1998; Ross et al. 1989). This information is primarily focused on different types of limestone, sandstone and marble because they are typically used in the northern hemisphere to create buildings, statues, tombstones and monuments. The decay of carved stone focussing on gravestones has also been investigated (Charola 1998). Studies have found that various stone types react differently, for example, a study by Girardet and Furlan (1998) using five different types of stone (Berne and Villarlod molasses, Jaumont and Beaune limestones and Carrara marble) found that marble and less porous Beaune limestone had low reactivity to 75 ppb of sulfurous acid at low relative humidity and decreasing temperatures, while the other stones showed high reactivity (Charola 1998). Another study (Furlan and Girardet 1988) looked at dry deposition on four types of stone (Swiss calcareous limestone, two French limestones and Italian Carrara marble) and found that reactivity increased from the marble to the limestone with rock porosity being a significant factor; the more porous rocks were most affected. While a significant body of knowledge exists on the decay processes on stone built monuments especially in the northern hemisphere, the parallels with rock art erosion are yet to be fully explored (Barnett and Diaz-Andreu 2005).

There is no scientific evidence currently available demonstrating that industrial emissions have accelerated rock art weathering on the Burrup Peninsula, or damaged the rock art. The research undertaken to date in the northern hemisphere is not directly applicable to the Burrup Peninsula, as the Burrup Peninsula petroglyphs have been created on granophyric rhyodacite and to a lesser extent on gabbro and granite, not the carbonate or calcareous rocks used for sculptures and buildings in the northern hemisphere. Granophyric rhyodacite is one of the strongest rock types in Australia (Vinnicombe 2002). **Table 11-3** shows various properties of rocks and demonstrates that granite and gabbro are generally denser and less porous than limestone and sandstone although they have similar properties to marble.

Åberg and Stray (1999) examined the impact of atmospheric pollutants on a 4500 year old rock carving in Oslo, Norway, but weathering processes also had to account for salt deposition (from the de-icing of a nearby road) and mechanical weathering from freeze-thaw cycles due to sub–0°C temperatures. In Korea, a comprehensive study into the weathering of the Bangudae petroglyph was undertaken (Fitzner et al. 2004). However, the risk to this rock art relates to annual submersion of the petroglyph by the Daegok River following the construction of the Sayeon dam in 1965 and not atmospheric based weathering. Studies of petroglyphs deteriorating due to anthropogenic weathering activities (for example, Åberg and Stray (1999) and Fitzner et al. (2004)) cannot be applied to the Burrup Peninsula because the environment, rock material and weathering processes are not comparable.

The granophyric rhyodacite of the Burrup Peninsula is typically blue-grey rock with a surface coating that is weathered to a deep reddish-brown. This surface coating is known as rock varnish (**Section 10.3**). The contrast of the red-brown rock varnish and the lighter coloured layers underneath make the Burrup Peninsula petroglyphs readily visible, although the colour contrast varies and some petroglyphs have minimal or no colour contrast if there is little depth to the engraving (Vinnicombe 2002). It is suggested that acid deposition on the Burrup Peninsula will increase the rate of rock varnish formation, which will in turn make it difficult to see the petroglyphs as deep, lighter-coloured engraved lines become the same re-brown exterior colour. However, it is not yet understood how rock varnish is formed (Perry et al. 2003; Dorn 2004a; Bhatnagar and Bhatnagar 2005, Lau et al. 2005) therefore no conclusions can currently be made regarding the time it takes to form rock varnish.

There is perception that dark smoke results in significant release of particulate matter, which may impact on rock art. Dark smoke is primarily a visual impact, although it does consist of particulate matter. The contribution of dark smoke to impacts on rock art is currently under investigation by the Burrup Rock Art Committee.

Table 11-3 Relative Properties of Various Rocks (Attewell and Farmer 1976)

Typical Rock Types	Compressive Strength (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Bulk Density (Mg/m^3)	Porosity %
Granite	100–250	7–25	14–50	2.6–2.9	0.5–1.5
Gabbro	150–300	15–30	NA	2.8–3.1	0.1–0.2
Basalt	100–300	10–30	20–60	2.8–2.9	0.1–1.0
Marble	100–250	7–20	NA	2.6–2.7	0.5–2
Slate	100–200	7–20	15–30	2.6–2.7	0.1–0.5
Quartzite	150–300	10–30	20–60	2.6–2.7	0.1–0.5
Sandstone	20–170	4–25	8–40	2.0–2.6	5–25
Shale	5–100	2–10	3–30	2.0–2.4	10–30
Limestone	30–250	5–25	10–50	2.2–2.6	5–20
Dolomite	30–250	15–25	NA	2.5–2.6	1–5

Predicted Air Emission Impacts

As discussed above, the concerns regarding rock art deterioration are related to acid deposition, with sulfur dioxide and nitrogen dioxide being the key components as these emissions can lead to elevated levels of sulfurous acid, sulfuric acid and nitric acid. Other concerns are that acid deposition on the Burrup Peninsula will increase the rate of rock varnish formation, or that particulate matter released from dark smoke may impact on petroglyphs.

To address the uncertainty and lack of available scientific information on air emission impacts on the Burrup Peninsula rock art, the DoIR appointed the Burrup Rock Art Monitoring Management Committee to assess whether there has been any change to the petroglyphs over and above that due to natural weathering. The Committee has commissioned CSIRO Atmospheric Research to conduct an air pollution monitoring programme. Several studies into rock art appearance have also been commissioned by the Committee, with the work primarily done by CSIRO Manufacturing and Infrastructure Technology and some input from CSIRO Exploration and Mining.

All of the studies commissioned by the Burrup Rock Art Monitoring Management Committee will be peer reviewed and made publicly available. The studies commenced in 2004 and are due for completion in 2007. The first interim results/progress reports were released in 2005 (DoIR 2006).

The CSIRO Atmospheric Research monitoring programme focuses on monitoring ambient concentrations of air pollutants on the Burrup Peninsula (Gillet et al. 2005). Eight study sites were selected, two of which are sufficient distance from the industrial areas and anthropogenic influences to measure 'local background' or ambient conditions. An additional two sites outside the Burrup Peninsula were selected to provide a comparison of gas concentrations on the Burrup Peninsula with those in adjacent urban and non-urban areas respectively.

Passive samplers have been installed to record a range of pollutants and dust in the air and on the rock surfaces. Data is collected at each site for nitrogen dioxide, sulfur dioxide, ammonia, nitric acid, BTEX gases (benzene, toluene, ethylbenzene and xylene) and aerosols such as air pollutant particles (TSP, PM_{10}). The samplers have the capacity to record dry and wet deposition. Background parameters like temperature, humidity, wind speed and wind direction are also collected (Gillet et al. 2005).

Interim results from August 2004 to March 2005 (**Table 11-4**) show that there is some increase of nitrogen dioxide and sulfur dioxide above local background levels, but these increases are considered to be small (Gillet et al. 2005).

The local background concentrations of nitrogen dioxide are comparable to background concentrations at undisturbed locations, for example, 0.75 ppb of Charles Point west of Darwin and 0.8 ppb in the Cameron Highlands north of Kuala Lumpur. In contrast, the background concentrations of sulfur dioxide on the Burrup Peninsula are significantly lower than the sites near Darwin and Kuala Lumpur with recordings of 0.75 ppb and 0.5 ppb respectively (Gillet et al. 2005). Very low sulfur dioxide concentrations are possible in areas not impacted by anthropogenic pollution. For example, sulfur dioxide levels have been recorded at <20 ppt at the South Pole and <15 ppt at Baring Head, New Zealand (Gillet et al. 2005).

Table 11-4 CSIRO Atmospheric Research Interim Results for Nitrogen Dioxide and Sulphur Dioxide Monitoring (Gillet et al 2005)

Location	Local Background Concentrations	Industrial Area Concentrations
Nitrogen dioxide	0.5 ppb	2 ppb
Sulfur dioxide	100–160 ppt	191 ppt

Note: ppb = parts per billion; ppt = parts per trillion

To forecast the emissions associated with the Pluto LNG Development, TAPM air modelling has been undertaken including predicted levels of sulfur dioxide and nitrogen dioxide. **Table 11-5** and **Table 11-6** provide data on air emissions on the Burrup Peninsula, taking into account existing air emissions sources such as the NWSV Karratha Gas Plant, Hamersley Power Station and Burrup Fertilisers Ammonia Plant. Detailed discussion on air emissions is provided in **Section 5.2.1**, **Section 9.5.1** and SKM (2006a).

The annual averages and deposition rates presented in **Table 11-5** and **Table 11-6** are based on TAPM modelling results, and are much higher then the data recorded by CSIRO monitoring. This is not unexpected, as the modelling study was primarily concerned with identifying worst-case, short-term impacts. Consequently, model inputs considered some emissions sources that are known to be highly variable as constant, relatively high emissions sources. The marine ship-loading flare and shipping activity are such examples. Shipping is the most significant source of sulfur dioxide associated with the Pluto LNG Development and it has been assumed that shipping is a daily activity, when in reality it will only occur approximately once every five days. As a result, model results are considered to be a conservative over-estimation of the actual ground-level concentrations measured by the CSIRO monitoring study. The same assumptions were modelled for both the 'existing case' and the 'Pluto LNG Development forecasting' scenarios. The following conclusions can be drawn from the air modelling exercise:

- ambient annual averages of nitrogen dioxide will increase slightly on land due to the Pluto LNG Development
- ambient annual averages of sulfur dioxide are unlikely to increase on land due to the Pluto LNG Development
- any nitrogen dioxide deposition due to Pluto LNG Development emissions are insignificant
- any sulfur dioxide deposition due to the Pluto LNG Development contributes an insignificant amount to existing sulfur dioxide depositions in the Burrup Peninsula region.

Field Studies of Rock Art Appearance

There are four components to the CSIRO field studies into rock art appearance commissioned by the Burrup Rock Art Monitoring Management Committee. These studies investigate physical, chemical and mineralogical changes in the rock surface with an emphasis on determining early indicators of damage. The current status of each study, as reported in the interim report (Lau et al. 2005) is summarised below:

- Fumigation – in laboratory conditions, rock samples will be exposed to simulated climatic cycles to replicate weathering that occurs on a scale of years in a much shorter timeframe. The fumigation studies will be carried out on current, future and at 5–10 times the future pollutant estimates. At the time of interim reporting (Lau et al. 2005), researchers were working to establish baseline information for the critical parameters of surface temperature and surface wetness, rock mineralogy and appropriate climatic cycles.
- Dust deposition – airborne dust deposited on rock surfaces may potentially alter petroglyph images that are defined by the contrast between the rock engraving and background. This study involves monitoring dust deposition on rock surfaces and through chemistry and mineralogy, determines the origin of the dust. Researchers have established that substantial differences exist in the chemistry and mineralogy of the local soil and iron ore dust. Once sufficient dust has accumulated on exposed tiles used to simulate rock surfaces, qualitative and comparative measurements will be performed (Lau et al. 2005).
- Colour change – this study involves in-situ monitoring of seven petroglyphs using hand-held spectrophotometry to assess colour change. Measurements are taken from both engraved and background (unmarked rock surface) areas for each petroglyph. This is an annual monitoring programme which will be undertaken over four years. At the time of interim reporting (Lau et al. 2005), only the first baseline recording had been taken. The first annual measurements of colour change indicate that there is no clear evidence of colour change in petroglyphs (Murray 2006).
- Spectral Mineralogy – this study has the overall objective to assess the mineralogy and to monitor the mineralogical changes (if any) of the same seven petroglyphs used in the colour change study. Again, only baseline data were reported at the time of interim reporting (Lau et al. 2005); however, preliminary data from the first annual measurement indicate that the mineralogy of the rock surfaces has not changed during the monitoring period and therefore there is no clear evidence of mineralogical change in petroglyphs (Murray 2006).

In addition to the CSIRO studies into rock art appearance, Murdoch University has been commissioned by the Burrup Rock Art Monitoring Management Committee to conduct microbiological studies of rock surfaces. Samples were collected in July 2004 and September 2005. Interim results indicate very low populations of bacteria, with most samples showing no evidence of viable bacteria (Murray 2006).

Woodside supports the studies commissioned by the Burrup Rock Art Monitoring Management Committee into air pollution and rock art appearance. In addition to this, Woodside (as the NWSV operator) has commissioned independent heritage audits to map heritage sites on NWSV leases on the Burrup Peninsula. They have also commissioned heritage surveys to identify and map rock art and heritage sites within the Pluto LNG Development areas. In 2007, Woodside will introduce a three-year scholarship in honour of Dr Pat Vinnicombe for research related to heritage management on the Burrup Peninsula.

Table 11-5 Predicted Annual Averages of Nitrogen Dioxide and Sulfur Dioxide (SKM 2006a)

Emissions	NEPM Standard[1] (Annual Average)	Existing Case (Annual Average)	Pluto Forecasting (Annual Average)
Nitrogen dioxide	30 ppb	Maximum 4 ppb onshore	Maximum 5 ppb onshore
		Maximum 8 ppb offshore	Maximum 9 ppb offshore
Sulfur dioxide	20 ppb	Maximum 1 ppb onshore	Maximum 1 ppb onshore
		Maximum 6 ppb offshore	Maximum 6 ppb offshore

Note 1: The National Environmental Protection (Ambient Air Quality) Measure (NEPM) (NEPC 2003) does not relate to petroglyph or granite deterioration but has been provided as a general point of reference.

Table 11-6 Predicted Annual Deposition of Nitrogen Dioxide and Sulfur Dioxide (SKM 2006a)

Emissions	WHO Standard[1]	Existing Case (Annual Average)	Pluto Forecasting (Annual Average)
Nitrogen dioxide	49–66 kg/ha/annum	Maximum 3 kg/ha/annum onshore	Maximum 3.5 kg/ha/annum onshore
		Maximum 1.5 kg/ha/annum offshore	Maximum 2 kg/ha/annum offshore
Sulfur dioxide	8–16 kg/ha/annum	Maximum 2 kg/ha/annum onshore	Maximum 2 kg/ha/annum onshore
		Maximum 12 kg/ha/annum offshore	Maximum 12 kg/ha/annum offshore

Note 1: The World Health Organisation (WHO) standard does not relate to petroglyph or granite deterioration but has been provided as a general point of reference.

11.4.1 Preventative and Management Measures

Woodside's approach to the management of Aboriginal heritage has been developed to ensure the requirements of the Aboriginal Heritage Act and the EP Act are met in relation to identification, assessment and management of significant sites.

The approach is based on a policy of minimal disturbance, which is implemented via a step-wise approach, as follows:

- Probability of occurrence of Aboriginal heritage sites is used as a constraint in site selection decision-making (refer to **Section 3.2.1**).
- Conduct of thorough archaeological and anthropological heritage surveys and consultations with relevant Indigenous groups to develop a detailed understanding of the heritage landscape.
- Use survey results and consultations to develop design footprints that avoid disturbance to Aboriginal heritage sites as far as practicable.
- Where disturbance to sites is unavoidable, seek permission under Section 18 of the Aboriginal Heritage Act to retrieve, relocate and where this is not possible, disturb Aboriginal heritage material.
- Develop detailed heritage management plans in consultation and collaboration with Aboriginal people and the state government.

The occurrence of high densities of significant Aboriginal heritage sites was used as a socio-economic constraint during the site selection process for the Pluto LNG Development. Further details of the site selection process are detailed in **Section 3**.

Comprehensive archaeological and anthropological heritage surveys of Site A and Site B have been conducted. Anthropological surveys included representatives from the Ngarluma and Yindjibarndi, Wong-Goo-Tt-Oo and Yaburarra and Mardudhunera groups. Woodside engaged heritage consultants ACHM to undertake detailed archaeological surveys and/or heritage site verification surveys of Site A and Site B.

Woodside will continue to take a focused consultative approach to both mitigate and manage the impacts to heritage sites and protect heritage sites that lie outside of the Pluto LNG Development area. To date this approach has been effective, with Woodside being able to leave an estimated 95% of rock art undisturbed and in-situ across the Pluto LNG Development area as a result of carefully considering heritage survey results during the infrastructure design phase and seeking and acting on advise from the Indigenous groups of the area and other experts.

Woodside has adopted a focused consultative approach to heritage management and this approach has resulted in over 95% of rock art being located outside of the Pluto LNG Development disturbance footprint. Woodside will continue with this approach as a central premise to both manage the impacts to heritage sites within the Pluto LNG Development disturbance footprint and to protect heritage sites outside of the disturbance footprint.

In addition to this consultative process, Woodside will develop and implement a comprehensive Cultural Heritage Management Plan with the involvement of representatives from the Ngarluma and Yindjibarndi, Wong-Goo-Tt-Oo and Yaburarra and Mardudhunera groups and other experts that will set a sound framework for how Woodside will conduct its activities during the development and operational phases of Pluto LNG Development. This plan will also set out how Indigenous representatives will assist Woodside to manage heritage and access heritage sites within the Woodside lease areas during the construction and operation phases.

Where relocation is required, approval will be sought to move sites to suitable conservation areas, in consultation with relevant Indigenous groups. Woodside's preferred practice is to avoid disturbing heritage sites. As many sites as possible will be left in-situ.

The mitigation and management measures that will apply to all activities at Site A and Site B are detailed below. These measures will be finalized in consultation with Indigenous groups and other experts.

Separate Cultural Heritage Management Plans (CHMP) will be prepared and implemented for Site A and Site B. **Table G-15**, **Appendix G** outlines the framework plan. Measures that will be implemented as part of CHMPs will include but not be limited to the following:

- Disturbance to sites will be minimised as far as possible. Where disturbance to sites cannot be avoided, heritage sites will be relocated to designated conservation areas.
- Any proposed disturbance to cultural heritage sites will be subject to application under Section 18 of the Aboriginal Heritage Act.
- Aboriginal sites near work areas will be managed to prevent avoidable impact.
- A cultural heritage induction will be included within the Pluto LNG Development site access inductions.
- Initial site preparation works will be monitored by Aboriginal representatives and archaeologists.

- Any archaeological discoveries during site preparation work will be reported to the regulatory authority in accordance with reporting and mitigation measures identified in the CHMP, state government policy and the expectations of the Indigenous groups.
- Aboriginal representatives will be involved in all stages of mitigative relocation.
- Access to conservation areas by Indigenous groups will be maintained, subject to operational and occupational health, and safety constraints.

Proposed management measures are summarised in **Table 11-7**.

Residual Risks

The implementation of a CHMP and other management measures will reduce the overall extent of disturbance to Aboriginal heritage sites by leaving the most significant sites in-situ and outside the disturbance area. Nevertheless, due to the likely disturbance of some cultural heritage sites, the consequence is considered minor and the residual risk medium. As clearing and earthworks will definitely occur regardless of what management measures will be implemented this risk rating is considered appropriate.

11.5 European Heritage

Potential Impacts

As described in **Section 10.4**, several heritage places listed on the Register of the National Estate and the Register of the Heritage Council of WA occur in the general vicinity of the Pluto LNG Development. However, the nearest registered historical sites to the Pluto LNG Development are all approximately 7.5 km from Site A and Site B. Given the distance of these places from the actual development and the nature of the proposed activities it is highly unlikely that any of these listed places will be affected. Risk to any listed heritage place is therefore considered low.

Preventative and Management Measures

In the absence of impacts no specific management measures are required beyond those measures already described throughout this section of the Draft PER.

Residual Risks

Residual risks are considered low.

Table 11-7 Summary of Impacts, Management and Risks of Aboriginal Heritage

<table>
<tr><th rowspan="2">Aspect</th><th rowspan="2">Activity, Event or Source</th><th rowspan="2">Affected Environment or Impact</th><th rowspan="2">Mitigation/Control Measure</th><th colspan="3">Residual Risk</th></tr>
<tr><th>C</th><th>L</th><th>RR</th></tr>
<tr><td rowspan="3">Degradation of Aboriginal heritage sites within Development area</td><td>Clearing of vegetation</td><td>Disturbance to Aboriginal sites</td><td rowspan="4">Sites will be avoided as far as possible. Where disturbance to sites cannot be avoided, Woodside intends to relocate archaeological material to areas within the Pluto lease.
Disturbance to cultural heritage sites will be subject to application under Section 18 of the Aboriginal Heritage Act.
Aboriginal sites near work areas will be managed to prevent avoidable impact.
A cultural heritage induction be included within the Pluto LNG Development site access inductions.
Initial site preparation works will be monitored by Aboriginal representatives.
Any archaeological discoveries during site preparation work will be reported to the regulatory authority in accordance with reporting and mitigation measures identified in the CHMP, state government policy and the expectations of the Indigenous groups.
Aboriginal representatives will be involved in all stages of mitigative relocation.
Access to Site A non-disturbance areas by Indigenous groups will be maintained, subject to operational and occupational health, and safety constraints.</td><td>D</td><td>5</td><td>M</td></tr>
<tr><td>Earthworks</td><td>Disturbance to Aboriginal sites</td><td>D</td><td>5</td><td>M</td></tr>
<tr><td>Vehicle, plant and equipment movements</td><td>Inappropriate access by workforce; disturbance to Aboriginal sites</td><td>E</td><td>1</td><td>L</td></tr>
<tr><td>Degradation of heritage sites outside of the Development area</td><td>Clearing, earthworks or other activities</td><td>Damage to or loss to heritage sites</td><td>E</td><td>1</td><td>L</td></tr>
</table>

**C – Consequence; L – Likelihood; RR – Residual Risk*

11.6 Land Use and Land Tenure

Potential Impacts

The Pluto gas field, located in exploration permit WA-350-P, is currently undeveloped and Woodside is the sole equity owner. With the exception of occasional shipping activity and possible minor fishing activity, the permit area is presently unused. The proposed gas trunkline route traverses permits operated by other petroleum companies; although, the small, linear footprint of the route is not expected to impact significantly on those permits.

Site A and Site B are currently vacant and zoned for industrial use under the Burrup Land Use Plan and Management Strategy (BPMAB 1996). The proposed development will modify the surface within the site footprints, but will essentially have negligible impact on the land use and tenure. With appropriate management measures, risk to existing roads, railways and pipelines is considered low.

Preventative and Management Measures

Advance notification will be provided to, and liaison undertaken with, the lease holders of offshore permit areas that will be transected by the trunkline. Similarly, the owners of leased land lots will be given advance notice of construction activities and consulted. Proposed management measures are summarised in **Table 11-8**.

Residual Risks

Provided that Woodside liaises with the relevant land and permit lease owners and provides them with advanced notification of intended works, residual risks are considered to be low.

11.7 Protected Areas

Potential Impacts

There are several existing marine protected areas in the vicinity of the Pluto LNG Development including Ningaloo Reef Marine Park, Muiron Islands Marine Management Area and Cape Range National Park, located 220 km, 204 km and 258 km away from the Development, respectively. Existing terrestrial protected areas in the vicinity include a number of island nature reserves including Dampier Archipelago Nature Reserves, Great Sandy Islands Nature Reserve and the Lowendal Island Nature reserve, located 1 km, 50 km and 58 km away from the Pluto LNG Development, respectively. Given their distance, the Pluto LNG Development is unlikely to have any direct impacts on these existing areas.

A number of marine parks and management areas are proposed in the vicinity of the Pluto LNG Development. The Montebello/Barrow Islands Marine Conservation Reserve and the proposed Dampier Archipelago Marine Park are located 27 km and 1 km, respectively, away from the gas trunkline route.

Potential impacts to these proposed areas are considered minor. The routing of the offshore gas trunkline, marine discharge pipeline and location of dredging area and dredge spoil disposal grounds have been selected to avoid protected areas and the values associated with these areas.

Preventative and Management Measures

No impacts are expected therefore no specific management measures, beyond those already described in the Draft PER, are proposed.

Residual Risks

Residual risks to protected areas are considered low.

11.8 Fisheries

Potential Impacts

The potential impacts to fisheries arising from the proposed Development are:

- loss of access to commercial and recreational fishing grounds
- loss of livelihood or income resulting from accidental hydrocarbon or chemical spills in the vicinity of the Development
- disturbance to fish habitat, feeding and spawning areas and migration routes
- snagging of fishing nets on subsea equipment
- temporary disturbance to fish habitat associated with elevated TSS and sedimentation concentrations from dredging and dredge spoil disposal activities.

Table 11-8 Summary of Impacts, Management and Risks of Land Use and Land Tenure

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Land Use and Land Tenure	Onshore and offshore trunklines	Intersection of leased offshore permit areas and land leases	Advanced notification of intended works and liaison with lease/permit owners	D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Loss of short-term access to commercial and recreational fishing grounds may occur due to construction activities. Long-term access restrictions will involve exclusion zones around permanent features such as the offshore riser platform and some restriction of trawling grounds due to exposed sections of the offshore gas trunkline.

Fisheries that report activity in the vicinity of the Pluto LNG Development, have been described in **Section 10** and include:

- The North West Slope Trawl Fishery (Cwth): given the very small proportion of fishing grounds that might be lost, impacts are considered slight.
- The Western Tuna and Billfish Fishery (Cwth): fishers are unlikely to be in close proximity to, or interact with the offshore platform.
- The Pilbara Fish Trawl (Interim) Managed Fishery (WA): the gas trunkline intersects a very small subsection of Area 1 (in zone 2) of this fishery. This subsection is reported as being significant in terms of catch and value. There is potential for minor impact on this fishery as a result of trawl equipment snagging on the trunkline and/or a restriction in fishing grounds.
- The Pilbara Trap Managed Fishery (WA): Given the nature of the fishing (small traps lowered to the ocean floor) and the number of operators (two), impacts on this fishery are expected to be slight.
- The Pearl Oyster Fishery (WA): Given the nature of this fishing (collection of shells by hand) and low intensity, potential impacts from the proposed Development are considered slight.
- The Onslow Prawn Managed Fishery (WA): there is limited potential for impacts on this fishery. The gas trunkline route avoids any areas that were trawled in 2004.
- The Wetline/Mackerel Fishery: Impacts are highly unlikely and are considered slight.

Potential impacts on recreational fishing resulting from the presence of the platform, exposed subsea pipelines/ trunkline and construction vessels are likely to be slight. Dredging and dredge spoil disposal activities have the potential to result in temporary impacts to recreational fisheries within Dampier Archipelago including line fishing and spear fishing areas.

Preventative and Management Measures

All aspects of the Pluto LNG Development will be undertaken in accordance with the *Fish Resource Management Act 1994* (WA).

A Dredging and Dredge Spoil Disposal Management Plan will include measures to mitigate against impacts on aquatic life for human consumption and recreational fishing activities in accordance with the Pilbara Coastal Water Quality Consultation Outcomes EQMF (DoE 2006a).

Proposed management measures are summarised in **Table 11-9**.

Residual Risks

Given that exclusion zones will be very small in relation to total fishing grounds, risks associated with reduced fishing grounds will be inherently low for affected fisheries. The implementation of exclusion zones will reduce risk of snagging by trawl fisheries on subsea facilities, as will marking such facilities on admiralty charts. Residual risks are shown in **Table 11-9**.

11.9 Infrastructure and Transport Network

Potential Impacts

The onshore components of the Pluto LNG Development have the potential to place added pressure on existing infrastructure and utilities that may not have the capacity to deal with this increased demand. Potential impacts on existing infrastructure and utilities include:

- damage to existing road surfaces from heavy construction vehicles entering and leaving the site
- pressure on existing traffic conditions
- pressure on existing sewage treatment and disposal facilities
- pressure on water supply
- pressure on local waste facilities
- pressure on local power supply.

Construction Phase Traffic Impacts

The construction phase, including transport of materials and workforce to and from site is likely to result in the most significant impacts on existing traffic levels. It is assumed that no road widening or upgrades will be required during this phase (**Section 4**). Transport of the pre-assembled units to site could have a significant impact on the local traffic conditions due to temporary road closures that are required to allow passage of larger modules. The precise number and time between each pre-assembled unit is not yet known and will need to be determined once details are available. It is anticipated that sections of MOF Road and the NWSV Haul Road will be used to transport materials into the south-west corner of Site B. Construction workforce will be transported along Burrup Road, entering Site B at the proposed car park located in the north-east corner of Site B.

Burrup Road is the only public road route to and from the Burrup Peninsula and it is therefore necessary that access is maintained during the construction activities. Similarly, access along the local roads such as MOF Road and King Bay Road within the Burrup Peninsula is essential for the operation of other industries such as the Dampier Port (for MOF Road). In particular, access for emergency vehicles will be required.

The construction workforce will be up to 3000 employees and they will be transported to and from Site A and Site B in buses. **Table 11-10** presents two scenarios to identify the potential impacts that may occur in the event that all workers drive to the construction sites. This assumes two workers per vehicle compared to the currently proposed use of buses. For the bus option it has been assumed that workers are transported to and from site with 20 workers per bus.

Based on there being up to 3000 employees travelling to and from the construction sites at Site A and Site B by bus, the level of service for the NWSV Haul Road north of MOF Road is likely to be LOS A. For Burrup Road, both to the north and south of King Bay Road, the level of service is likely to be LOS D. At LOS D the traffic is considered to be close to the upper limit of stable flow.

Table 11-9 Summary of Impacts, Management and Risks of Fisheries

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Commercial Fisheries	Reduction in fishing grounds due to exclusion zones around offshore platform, subsea installations and vessels and/or snagging on offshore platform and/or subsea installations	North West Slope Trawl Fishery Pilbara Trap Managed Fishery Wetline/Mackerel Fishery Western Tuna and Billfish Fishery Recreational fishing	Construction corridor for the offshore trunkline will be limited as far as practicable to reduce potential impacts to fish habitat, feeding and spawning areas. Information relating to the location of permanent Development components will be provided to the relevant authorities for representation on admiralty charts. Exclusion zones around platform and sub sea installations will be gazetted and marked on admiralty charts to reduce likelihood of collisions with the offshore platform and/or snagging of trawl gear on sub-sea installations. An exclusion zone will be established around the export jetty. An Oil Spill Contingency Plan will be developed (refer to **Section 7.10**). Advanced warning of construction and decommissioning vessels will be provided. Development and implementation of a Dredging and Spoil Disposal Management Plan that will minimise impacts on aquatic life for human consumption and recreational fishing activities in accordance with the Pilbara Coastal Water Quality Consultation Outcomes EQMF (DoE 2006a).	E	2	L
	Reduction in fishing grounds due to exclusion zones / risk of snagging on trunkline and marine discharge pipeline	Fishers in the Pilbara Fish Trawl (interim) managed Fishery		D	3	M
		Fishers in Onslow Prawn Managed Fishery and Nickol Bay Prawn Fishery		D	3	M
	Accidental hydrocarbon and chemical spills	Loss of livelihood or income resulting from impacts on fish stocks and fish catch quality		D	1	L
	Physical presence of offshore platforms, subsea installation sand pipelines	Disturbance to fish habitat, feeding and spawning areas and migration routes		C	0	L
	Dredging and dredge spoil disposal	Temporary disturbance to fish habitat from elevated TSS and sedimentation concentrations		D	1	L
Recreational Fisheries	Exclusion zones around construction vessels within the Dampier Archipelago	Restriction of recreational fishing grounds		D	1	L
	Dredging and dredge spoil disposal	Disturbance to recreational fishing within Dampier Archipelago as a result of an increase in TSS and sedimentation concentrations		D	3	M

**C – Consequence; L – Likelihood; RR – Residual Risk*

Table 11-10 indicates that in the event that workers travel to site in private motor vehicles, Burrup Road would experience a reduced level of service with the extra traffic and delays to vehicles. This is due to the expected LOS E and F on Burrup Road at various locations. This represents congested traffic. It should be noted that this assessment has been solely based on the assessment of the road links and not the intersections. There is expected to be greater impacts and delays at intersections based on the above link assessments.

It is anticipated that heavy machinery and construction vehicles will be stored on-site; therefore there will be minimal impact on the road network as a result of the daily operation of these vehicles.

The gas trunkline Options 1 and 2 will cross NWSV Haul Road in order for the trunkline to traverse from Site A to Site B. Dampier Road is an important road and as such needs to remain open at all times other than temporary event type closures (for example, less than fifteen minutes) under strict traffic management.

Notwithstanding the above, given that construction techniques at these crossings will not impact existing roads (that is, either horizontal directional drilling or thrust boring techniques will be used to tunnel under existing roads and railways) and that the duration of this activity will be limited, potential impacts are highly unlikely and are considered minor.

Further potential impacts during the construction phase of the Pluto LNG Development will arise if other large industrial developments are constructed in the vicinity of the Pluto LNG Development, within similar timeframes.

Based on the impacts of the Pluto LNG Development, it is estimated that should any one of the above projects coincide with the construction of the Pluto LNG Development and construction workers utilise private vehicles and not buses to travel to and from these sites each day then there could be major impacts on Burrup Road and other local roads (for example, LOS E).

Reference to **Table 11-10** indicates that in the event that workers drive to and from the sites in their own vehicles there may be significant impacts for construction of the Pluto LNG Development alone. Should other projects be constructed at the same time as the Pluto LNG Development and should the workforce drive private motor vehicles between the construction sites and Karratha/ Dampier then the level of service of Burrup Road is expected to drop during peak periods. The potential for this to occur can be reduced or eliminated through appropriate management to ensure that the peak traffic demands for each development and operation do not coincide and/ or by encouraging greater use of buses to take workers to and from the construction sites.

During the construction of Site A and Site B there will be a requirement to deliver materials between the existing Dampier Port MOF and the two sites. This will result in a requirement to close off portions of the following roads to allow these loads to pass:

- MOF Road between the MOF and NWSV Haul Road
- NWSV Haul Road between MOF Road and Site A/B.

The impacts of these closures will be such that no traffic will be able to drive along these roads apart from the loads. If the vehicles carrying the pre-assembled units travel at approximately 5 km/h the estimated time that each of these roads will need to be closed to traffic for pre-assembled unit are:

- MOF Road (between NWSV Haul Road and the Dampier Port) – 15 minutes
- NWSV Haul Road – 15 minutes.

Multiple pre-assembled units will increase these time frames and will be dependant upon the material offloading procedure/ rationale. The impacts of these temporary road closures will be that traffic will not be able to pass including emergency vehicles. This would apply to access to the MOF, Site A and Site B at various times during the traverse of large loads requiring road closures.

Table 11-10 Expected Road Level of Service during Construction (not including Pre-Assembled Unit Haulage)

Road	Existing	Private Vehicle	Bus
NWSV Haul Road north of MOF Road	A	A	A
MOF Road west of NWSV Haul Road	A	A	A
MOF Road north of King Bay Road	A	A	A
King Bay Road east of MOF Road	A	A	A
Burrup Road south of King Bay Road	C	F	D
Burrup Road north of King Bay Road	C	E	D

Note: Refer to Section 10 for classification of level of road service

Operation Phase

During operations the workforce, estimated to be up to 200, will work in shifts; however, the number of employees will slightly reduce the operating level of service along Dampier Road and Burrup Road if they are all to travel to and from work individually. **Table 11-11** summarises the level of service of the roads anticipated during operation. It is anticipated that the roads will be able to accommodate the traffic associated with operations. Potential impacts are therefore considered minor.

Preventative and Management Measures

Potential impacts on existing infrastructure and transport network will be mitigated by implementation of the following measures summarised in **Table 11-12**.

Management measures to limit impacts on traffic will include consultation and coordination with MRWA and the Shire of Roebourne on all activities that have potential to affect the local road network. In particular, road closures associated with the movement of any slow moving vehicles will take place outside peak traffic times for normal traffic.

During construction, where practicable, workers will travel to sites via bus, as will those workers needing to move between sites via the road network. The potential for compounded impacts resulting from other possible industrial project construction activities in the vicinity may be mitigated through consultation with the developers of those projects, to coordinate activities such that at least one project avoids peak traffic periods.

A Traffic Management Plan will be developed and implemented as summarised in **Table 11-12**.

Residual Risk

Given the potential for the Development to be self-sufficient in terms of power, water and sewage treatment and with the implementation of Traffic Management and Waste Management Plans, residual risks to utilities and infrastructure are expected to be low.

During the construction phase, provided that consultation with the relevant authorities occurs, and that a Traffic Management Plan with the measures outlined above are implemented, residual risk is expected to be medium. Residual risk to traffic due to the crossing of roads by the onshore trunkline is expected to be low.

During the operation phase, residual risks to road users from increased traffic volumes are considered low.

11.10 Marine Traffic

Potential Impacts

Potential impacts to existing marine traffic and navigation users during the construction, operation and decommissioning activities associated with the Pluto LNG Development may include:

- loss of access to the area due to the presence of permanent and temporary facilities and vessels
- navigational hazards represented by permanent structures, particularly the offshore platform.

Temporary vessels include the drill rig, pipe laybarge and support vessels, while permanent facilities include the offshore riser platform, nearshore jetty and causeway.

Within the vicinity of the Pluto gas field and the majority of the offshore gas trunkline, existing marine traffic is considered low and impacts throughout all phases of the Development are therefore highly unlikely and considered minor.

Shipping activity within the Dampier Archipelago, particularly through Mermaid Sound, is heavy and potential impacts from loss of access areas and navigational hazards (particularly during channel dredging) are possible, and considered moderate.

Preventative and Management Measures

A gazetted safety exclusion zone of 500 m radius from the outer edge of the platform and associated structures or equipment will be required to protect the facilities and to reduce the risk of marine collisions. This safety zone will appear on Australian

Table 11-11 Operational Level of Service

Road	Level of Service (LOS)	
	Existing	During Operational Phase
NWSV Haul Road north of MOF Road	A	A
MOF Road west of NWSV Haul Road	A	A
MOF Road north of King Bay Road	A	A
King Bay Road east of MOF Road	A	A
Burrup Road south of King Bay Road	C	C
Burrup Road north of King Bay Road	C	C

Table 11-12 Summary of Impacts, Management and Risks of Infrastructure and Transport Network

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Infrastructure and Transport Network	Use of existing roads, power, water, sewage and waste disposal facilities during construction, operation and decommissioning phases	Pressure on existing infrastructure and utilities	Sewage treatment and disposal facilities will be provided during onsite during construction and operation (refer to **Section 5**). Potable water supplies will be provided by the Water Corporation mains supply; however, requirements above 200 000 m^3/ yr will most likely be provided by a new desalination plant. All operations will be self-sufficient with regards to power generation. Development of Waste Management Plans for each phase of the development to ensure correct and prompt disposal or management. The plans will include avoidance, recycling, reuse and recovery options.	D	1	L
	Transport of modular/stick components	Road closures on MOF Road and NWSV Haul Road	Develop and implement a Traffic Management Plan that will include the following measures: • Emergency access will be provided for at all times. • Identify existing traffic volumes on the public road network. • Determine the traffic flow as a result construction activities. • Identify construction periods which will result in lessened impact on existing public road network traffic. • Monitor the impact of heavy vehicles on the public road network. • Identify the location of truck lay-up areas to be used outside of their usage periods. • Advise on the access restrictions imposed on each vehicle type. • Provide nominated personnel responsible for each traffic management activity. • Assessment of intersections suitable for the movement of pre-assembled units and provision of advice on the required changes to accommodate these	D	3	M
		Delays to Emergency Vehicles		D	1	L
	Workers commuting to site during construction phase	Increased traffic volumes along Burrup Road, NWSV Haul Road and MOF Road		D	3	M
	Workers commuting to site during operation phase	Increased traffic volumes along Burrup Road, NWSV Haul Road and MOF Road		E	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

navigation charts. Safety equipment such as markers, navigation aids, fog horns and illumination lighting will be installed on the offshore platform, and all lights and markers will adhere to the internationally recognised International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) standards.

Potential impacts from construction of the gas trunkline Option 2 across the existing NWSV shipping channel will be minimised by restricting the pipe laybarge from entering the shipping channel during tanker approach and departures. Consultation will be undertaken with the NWSV to avoid any potential impacts.

Proposed management measures are summarised in **Table 11-13**.

Residual Risks

Implementation of a gazetted safety exclusion zone and the installation of safety equipment on the offshore platform will result in residual risk associated with the platform being low. Residual risk to existing shipping through loss of area throughout the development area is considered low.

Table 11-13 Summary of Impacts, Management and Risks of Marine Traffic

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Marine Traffic	Presence of permanent and temporary facilities and vessels	Loss of access and navigational hazards represented by permanent structures within the Pluto gas field	A gazetted safety exclusion zone of 500 m radius around the offshore platform and associated structures or equipment Exclusion zone will appear on Australian navigation charts. Safety equipment such as markers, navigation aids, fog horns and illumination lighting will be installed on the offshore platform. Lights and markers will adhere to the internationally recognised IALA standards. Restricting the pipe laybarge from entering the NWSV shipping channel during tanker approach and departures. Consultation will be undertaken with the NWSV to avoid any potential impacts.	D	1	L
		Loss of access and navigational hazards represented by construction vessels within the area of the offshore trunkline		D	1	L
		Loss of access and navigational hazards represented by permanent structures and construction vessels within Mermaid Sound		C	2	M
		Temporary loss of access by NWSV tankers to the existing shipping channel during construction of the gas trunkline Option 2		D	1	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

11.11 Tourism and Recreation

To the south of Holden Point and bordering Site A to the west, there is a sandy bay and beach which is used for recreational purposes; however, public road access to the beach is prohibited and access is therefore only possible by boat. As a result, the beach is visited by few recreational users. In light of this, potential impacts are considered minor and unlikely.

A series of construction related activities have the potential to impact on existing marine-based tourism and recreational activities within Dampier Archipelago. The installation of the gas trunkline through Mermaid Sound has the potential to cause temporary disruption to recreational diving and boating through elevated TSS concentrations within the water column. Similarly, dredging of the navigation channel and disposal of spoil at Spoil Ground A/B, its northern extension and into deep water spoil ground 2B may potentially disrupt these types of recreational activities. The subtidal reef to the north-east of Rosemary Island at the entrance to Mermaid Sound is used for diving and snorkelling and has been zoned for recreational use in CALM's Indicative Management Plan (2001) for the proposed Dampier Archipelago Marine Park. The continuous disposal of spoil into deep water spoil ground 2B for approximately 18 months has the potential to result in elevated TSS concentrations and sedimentation at this reef location during summer months when sediments will be disturbed along a north-south axis (**Section 7.9.7.7** and **Section 7.9**). The residual risk of impacts to the recreational values at this location are considered low given that TSS and sedimentation concentrations are predicted to be slightly elevated above background levels and restricted to summer months.

Spoil disposal into spoil ground A/B and the northerly extension has the potential to impact another area zoned for recreational use in CALM's Indicative Management Plan (2001), which includes Conzinc Island to the south-east of these spoil ground locations. Areas close to the proposed spoil grounds are predicted to experience elevated TSS and sedimentation concentrations during spoil disposal activities (**Section 7.9**). The residual risk to recreational values in the vicinity of spoil ground A/B and the northerly extension is considered medium.

Potential impacts, in terms of visual amenity, on locals and tourists using 4WD tracks, footpaths and paths leading to and around Hearson Cove and Hearson Cove Access Road are discussed in **Section 11.12**.

Preventative and Management Measures

A Dredging and Spoil Disposal Management Plan will mitigate against impacts on recreational diving and other primary and secondary recreational values and aesthetic values in accordance with the Pilbara Coastal Water Quality Consultation Outcomes EQMF (DoE 2006a).

Proposed management measures are summarised in **Table 11-14**.

Residual Risks

The residual risk is considered low.

11.12 Visual Amenity and Landscape Character

Impacts were assessed in accordance with the Guidelines for Landscape and Visual Impact Assessment (2002) and have been transferred into the Woodside Environmental Risk Assessment methodology (**Figure 7-3**). The full landscape and visual impact assessment process, including impact levels in accordance with the Guidelines for Landscape and Visual Impact Assessment are provided in SKM 2006d. Visual impacts from dark smoke during flaring are assessed in **Section 9.5.2**.

Potential Impacts

The assessment of potential impacts on visual amenity from operation of the gas processing plant has in part, been assessed using photomontages developed by Woodside from digital terrain elevation modelling and a 3D model of the plant generated from using preliminary facility design data. The modelling has been applied to both Site A and Site B to provide a preliminary indication of the eventual as built appearance from various receptors on the Burrup Peninsula. The initial modelling outputs presented in this Draft PER will be updated during Front End Engineering and Design when design specifications and heights are better defined.

Landscape Character

Landscape Character of the wider Burrup Peninsula: The baseline landscape character of the area is described in **Section 10**.

Landscape Character within the Development Footprint – Site A: Development of tank storage and export facilities at Site A will result in the loss of, or degradation of, the following landscape types:

- rock outcrops
- scree slopes
- incised drainage lines
- grassland steppe.

Potential landscape character impacts are likely to occur during construction and operation activities relating to the presence of infrastructure, vegetation clearance and the introduction of artificial or 'man made' elements into the landscape. The introduction of man-made rigid elements into the landscape at Site A, given that the site is situated between the Dampier Public Wharf and NWSV Karratha Gas Plant site is likely to impact on the landscape character.

Landscape Character within the Development Footprint – Site B: The proposed gas infrastructure and buildings associated with Site B will considerably change the landscape. Proposed works will involve removal of large quantities of rock, re-grading to 58–60 m and flattening of the undulating terrain with the removal of existing material. There are no signs of previous disturbance on the site. The introduction of man-made, rigid elements into the landscape is likely to have an impact, given the largely natural character of the site and surrounding area.

Table 11-14 Summary of Impacts, Management and Risks of Tourism and Recreation

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Tourism and Recreation	Blasting and other construction activities at Site A	Restriction of access to beach west of Site A and/or impacts on visitors from blasting and other construction activities	Measures that will be implemented to reduce potential impacts on existing recreational user groups include the erection of warning signs. An observer will also monitor the beach from a safe location (either on the beach or a nearby boat) to prevent boats landing or to stop blasting until the beach has been cleared.	D	1	L
	Elevated turbidity levels from dredging and spoil disposal	Impacts on water-based recreational activities such as diving and snorkelling and areas zoned for recreational use in CALM's Indicative Management Plan (2001)	A Dredging and Spoil Disposal Management Plan will mitigate against impacts on recreational diving and other primary and secondary recreational values and aesthetic values in accordance with the Pilbara Coastal Water Quality Consultation Outcomes EQMF (DoE 2006a).	D	3	M

**C – Consequence; L – Likelihood; RR – Residual Risk*

Visual Amenity

Visual Impacts on Business and Industrial Premises (Medium-low Sensitivity): The proposed development at Site A will be partially visible from Dampier Port and the NWSV Karratha Gas Plant. Views of the facilities at Site A from Woodside Supply Base and Mermaid Marine Services Facility will be largely screened by existing landforms (that is, rocky outcrops). Facilities at Site A are unlikely to be visible from other business and industrial premises in the local area.

As with Site A, the proposed development at Site B would be partially visible from Dampier Port and the NWSV Karratha Gas Plant. In the most part views from Woodside Supply Base and ancillary supply companies will be largely curtailed by existing landforms. Partial views of the 160 m high gas flare and higher parts of the proposed infrastructure, for example, the LNG trains, may be possible for certain locations within these visual receptors. In summary, the impacts of Site A and Site B on business and industrial premises are considered minor.

Visual Impacts on Road Network (Low Sensitivity): Views from King Bay Road towards the proposed facilities at Site A will be significantly curtailed by the existing landforms between Site A and the road.

The proposed development at Site B may be visible at the eastern extent of the road, near the junction of King Bay Road and Burrup Road. At this section of the road, the proposed emergency access roads, the taller parts of the LNG trains and the gas flare are likely to be visible above the ridgeline. Impacts from this low sensitivity receptor are judged to be moderate.

As road users pass along MOF Road towards Dampier Port, views of the proposed facilities at Site A and Site B will largely be curtailed by existing landforms (that is, rocky outcrops). However, as the road plateaus near the junction of the NWS Haul Road, the southern extent of the proposed storage and export facilities on Site A and the gas processing plant on Site B will be partially visible (**Figure 11-4** and **Figure 11-5**). Site A would be unlikely to be visible from other roads in the local area.

The majority of Village Road is in a steep cutting which will shield views of the proposed development at Site A and Site B. However, at the western-most extent of the road, users will have clear views on the proposed development at Site B (**Figure 11-6** and **Figure 11-7**). Given the open nature of the saline flats between the Hearson Cove Access Road and the proposed development at Site B, there is likely to be unrestricted views onto the facility by east-bound and west-bound road users. The most notable features of the Development will be the LNG trains in the foreground and the gas flare at the northern extent of Site B (**Figure 11-8** and **Figure 11-9**). The proposed development at Site A is unlikely to be visible from this receptor, given the presence of a significant intervening topography and the proposed infrastructure at Site B.

Infrastructure proposed for Site B will be highly visible from Burrup Road as road users cross the King Bay - Hearson Cove valley looking northwards. The LNG trains and the gas flare will be particularly visible from this location. From the northern extent of Burrup Road looking south, the proposed development on Site B will be less visible with only taller plant on the eastern boundary of the site visible above the high rock outcrop between the road and Site B (refer to **Figure 11-10** and **Figure 11-11**). Site A is unlikely to be visible from other roads in the local area with the exception of those roads discussed above.

Impacts of Site A on users of the local road network are envisaged to be minor whilst the impacts of Site B are considered to be moderate.

Visual Impacts on Rights of Way, Footpaths, Four Wheel Drive Tracks, Recreational Facilities, Beaches and Reserves (Medium-High Sensitivity): Recreational boat users and tourist vessels in Mermaid Sound will have unrestricted views of the export jetty, storage facilities and marine flare located within Site A with partial views of Site B and beyond. The facilities at Site A and Site B may also be visible from islands in the Dampier Archipelago including Malus Island and East Lewis Island.

The various footpaths and four wheel drive tracks around Hearson Cove climb onto high ground and therefore offer unrestricted views onto the proposed development at Site B. Users of the footpaths/tracks are likely to have unrestricted views from high ground of the LNG trains and the gas flare that would be sited at the southern extent of the proposed development. The proposed development at Site A is likely to be obscured by intervening topography at this location.

The four wheel drive track which extends beyond Village Road towards Cowrie Cove passes through a valley. The steep sides of this section of the King Bay-Hearson Cove valley are likely to obscure any views of the proposed development at Site A and Site B.

Hearson Cove is a significant recreational feature in the local area, accommodating regular visits from locals and tourists. Views of Site B from the southern section of the beach at Hearson Cove would be partially restricted by a dune structure separating the saline flats from the beach, however; taller features such as the gas flare may be visible above the dune. The proposed development at Site A is unlikely to be visible at Hearson Cove.

Figure 11-4 Photomontage Showing the Proposed Development at Site B from MOF Road Looking North East

Figure 11-5 Original Photo Location From MOF Road Looking North-East

Figure 11-6 Photomontage Showing the Proposed Development at Site B from the Junction of Village Road and Burrup Road

Figure 11-7 Original Photo Location at the Junction of Village Road and Burrup Road

Figure 11-8 Photomontage Showing the Proposed Development on Site B Looking North from Hearson Cove Access Road

Figure 11-9 Original Photo Location from Hearson Cove Access Road Looking North

Figure 11-10 Photomontage Showing the Proposed Development on Site B from Burrup Road Looking Northwards

Figure 11-11 Original Photo Location on the Eastern Side of Burrup Road Looking North

It is unlikely that facilities at either Site A or Site B will be visible from Karratha. However, it is possible that during flaring events, a glow in the night sky may be visible.

This beach is located within Site A and is not accessible by land. There are existing tracks that were previously used to drive through Site A to the beach (although this was technically illegal). The beach is however, occasionally accessed by boat by the members of the public. Unrestricted views of the facilities, most notably of the LNG jetty, the tanks and the flare will be afforded users of the beach. It is likely however, that boat access to the facility will be prohibited following construction of the plant. In addition, the facility will be seen in the context of existing infrastructure immediately to the north and south of Site A (Dampier Port and the NWSV Karratha Gas Plant).

The facilities at Site B, particularly the slug catcher, the eastern-most LNG trains and the gas flare are likely to be partially visible from Mermaid Sound, in the mid-distance, partially screened by infrastructure on Site A.

Preventative and Management Measures

During the Front End Engineering and Design phase of the Pluto LNG Development, the digital terrain elevation model will be used again to simulate the as built design specifications for facilities at Site A and Site B. The results of the additional modelling will be used to determine the requirement for landscaping mitigation measures including potentially installing rock, sand or soil bund walls. Such a structure could be made to resemble a sand dune or local rock outcrop. This option would require further investigation in order to ensure the structural stability of the bund whilst ensuring the location would not result in unacceptable environmental impacts. The possibility of reducing site levels to use surrounding landforms to screen the proposed development will also be investigated. In addition and where possible, buildings and infrastructure will be coloured to blend in with the surrounding terrain.

Residual Risks

Table 11-15 shows residual risks to landscape character and visual amenity from proposed development at Site A and Site B.

Table 11-15 Summary of Impacts, Management and Risks of Visual Amenity

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Visual Amenity	Presence of built form in a predominately natural landscape setting	Landscape character of the wider Burrup Peninsula	All equipment and other tools will be housed or stored as required following use. All waste will be stored in appropriate facilities in order to minimise waste escaping from the site and blowing towards publicly accessible locations, thereby causing a visual nuisance. During the Front End Engineering and Design phase the digital terrain elevation model will be used again to simulate the 'as built' design specifications for facilities at Site A and Site B. The results of the additional modelling will be used to determine the requirement for landscaping mitigation measures.	C	5	H
	Presence of built form on Site B	Change of landscape resulting in loss and degradation of the character of land as grassland steppe, rock outcrops, scree slopes and incised drainage lines within Site B		B	5	S
	Landscape character impact within Site A from upgrading to 16 m AHD, vegetation clearance and introduction of man-made elements	Loss of or significant degradation of the following landscape types: • rock outcrops • scree slopes • incised drainage lines • grassland steppe • tidal inlet		B	5	S
	Visual impacts from storage facilities and export jetty (Site A)	Business and Industrial Premises		D	5	M
		Road Network		D	3	M
		Rights of Way, Footpaths, Four Wheel Drive Tracks, Recreational Facilities, Beaches, Ocean and Reserves		B	3	H
	Visual Impacts from gas processing plant/laydown areas (Site B)	Business and Industrial Premises		D	5	M
		Road Network		C	5	H
		Rights of Way, Footpaths, Four Wheel Drive Tracks, Recreational Facilities, Beaches, Ocean and Reserves		A	5	S

**C – Consequence; L – Likelihood; RR – Residual Risk*

11.13 Military Zones

Potential Impacts

The Pluto gas field falls within a Western Australian Exercise Area (WAXA), and there is therefore potential for loss of military flight training opportunities in that area, and also for potential conflicts between aircraft servicing the Pluto LNG Development and military aircraft using the area for exercise. However, given that the Pluto gas field will be located on the extreme periphery of the WAXA, and that only a very small proportion of the WAXA may therefore be affected, impact is considered minor.

Preventative and Management Measures

Woodside will undertake ongoing consultation with the Australian Department of Defence to discuss potential conflicts and to identify and agree on any necessary management measures. Proposed management measures are summarised in **Table 11-16**.

Residual Risks

With appropriate consultation with the Australian Department of Defence, residual risks are expected to be low.

Table 11-16 Summary of Impacts, Management and Risks of Military Zones

Aspect	Activity, Event or Source	Affected Environment or Impact	Mitigation/Control Measure	Residual Risk		
				C	L	RR
Military Zones	Presence of offshore platform Service aircraft	Reduction of exercise area Conflict between service aircraft and military aircraft	Consultation with the Department of Defence to discuss potential conflicts and to identify suitable management measures, if required	D	0	L

**C – Consequence; L – Likelihood; RR – Residual Risk*

Safety Risk Assessment

12

12.1 Summary

Throughout the design, construction, operation and decommissioning phases of the Pluto LNG Development, Woodside is committed to reducing the health and safety risks to public, employees and contractors, to levels that are as low as reasonably practicable. Preliminary risk assessment has not identified any risks to public safety from the Pluto LNG Development or to construction and operating personnel at the facilities beyond acceptable levels or that exceed legislative safety and risk guidelines.

The construction, commissioning and operation of infrastructure will be subject to a rigorous Safety Case process, safeguarding delivery and operation of the Development in a manner that minimises the risk to workers and the community. Development risks have been identified and Woodside is familiar with managing such risks on previous projects and at their existing operating facilities.

The gas processing plant will process, handle and store large inventories of LNG and condensate. The potential for accidents is well understood and the design of the plant and other facilities will emphasise minimisation of the probability of an accident happening and mitigating an accident if it occurs.

If an accident does occur, it will be either offshore or in one of five areas onshore: the gas processing plant; product storage and loading facility; LNG or condensate tanker; an oil spill in nearshore or onshore areas; or in a pipeline easement to the gas processing plant. Separate emergency response plans will be developed for each contingency.

12.2 Woodside's Operational Health and Safety Commitments

The construction and operation of the Pluto LNG Development has the potential to give rise to various hazards with increased risks to workers and the public. Through its mission and values statements, HSE policies and guidelines, Woodside demonstrates a strong commitment to protecting the health and safety of its personnel, contractors and the general public. Woodside commits to minimising the associated risk levels to operating personnel and the public to As Low As Reasonably Practicable (ALARP) by applying the ALARP principle in decision-making and detailed design processes. ALARP means that risks will be reduced beyond legislative requirements where it is reasonably practicable to do so.

This commitment to minimising health and safety risk impact is demonstrated as follows:

- selecting the concept with lifecycle risks that are ALARP
- minimising the risk within the lifecycle of the option.

As a minimum, Woodside commits to satisfying all health and safety legislative requirements.

12.3 Safety Risk Acceptance Criteria

12.3.1 Worker Risk

There is no legislative requirement to limit the risk to personnel working on offshore facilities to a specific value beyond that of the risk being at ALARP levels. Woodside corporate policies, however, impose an acceptance criterion of an average individual risk per annum (IRPA) for the most exposed worker group of $<1 \times 10^{-3}$.

Woodside has also adopted worker IRPA acceptance criteria for onshore facilities of $<1 \times 10^{-3}$ as per offshore facilities.

12.3.2 Offsite Risk

Individual risk at a given location is generally expressed as the peak individual risk, defined as the risk of fatality to the most exposed individual located at the position for 24-hours of the day and 365 days in the year. Since residential areas tend to be occupied by at least one individual all the time, the above definition would easily apply to residential areas. A person indoors would receive natural protection from fire radiation and hence the risk to a person indoors is likely to be lower than to one in open air. In this study, the individual risk levels have been calculated for a person in open air.

For land uses other than residential areas (that is, industrial or commercial) where occupancy is not 100% of the time, individual risk is still calculated on the same basis. However, the criteria for acceptability are adjusted for occupancy. Criteria have been established by the EPA in Western Australia (Risk Assessment and Management: Off-site Individual Risk from Hazardous Industrial Plant, WA EPA Final Guidance No. 2, July 2000). The risk criteria are summarised in **Table 12-1**.

There are no sensitive land uses, residential areas or commercial activities in the vicinity of the Burrup Industrial Estate.

A risk of 10 per million per year, or 10^{-5}, effectively means that any person standing at a point of this level of risk would have a 1 in 100 000 chance of being fatally injured per year.

Table 12-1 WA EPA Risk Criteria

Land Uses	Maximum Individual Fatality Risk (per year)
Sensitive land uses - hospitals, schools, child care facilities, old aged housing	0.5×10^{-6}
Residential areas	1×10^{-6}
Any commercial activities, including offices, retail centres, showrooms, restaurants and entertainment centres, in buffer zone between industrial and residential zones	5×10^{-6}
Any non-industrial activities or active open spaces in buffer zone between industrial and residential zones	10×10^{-6}
Boundary of an industrial site (facility generating the risk) (maximum risk at boundary of the site which generates the risk)	50×10^{-6}
Boundary of an industrial site (facility subject to risk) (maximum cumulative risk imposed by all surrounding facilities)	100×10^{-6}

In addition to quantitative criteria, qualitative guidelines are also given to ensure that offsite risk is prevented and where that is not possible, controlled. For new proposals, in addition to meeting the quantitative criteria, risk minimisation and use of best practice must be demonstrated. These terms imply:

- *Best Practice:* new plant should be designed using best practicable engineering design and operated using best industry practice management systems.
- *Risk Minimisation:* regardless of calculated risk levels and criteria, risks should be reduced to ALARP.

12.4 Safety Risk Assessment Methodology

The hazard management and risk assessment process is ongoing throughout the duration of a project. At this early phase, interdisciplinary hazard identification workshops and coarse risk analysis have been conducted. The objectives of the risk analysis were to:

- assess the operations phase risk of the Pluto LNG Development facilities
- assist Woodside in selecting a concept with risk levels that are ALARP
- identify significant risk contributors where future mitigation measures may be viable
- assess offsite public risk to ensure compliance with risk acceptance criteria.

Established hazard identification techniques were used to identify all significant potential hazards and credible accident events for the facilities. This comprised a systematic review of the information currently available for the facilities. Consideration was also given to proposed safety systems and to the safety management philosophies, systems and procedures that will be put in place for operating facilities of this nature.

Table 12-2 summarises the typical principal safety risk contributors associated with the proposed Pluto LNG Development facilities.

The consequences of the events carried forward from the hazard identification are modelled using proprietary software packages. The events modelled include jet fires, vapour cloud explosions and pool fires. Representative hole sizes are used to characterise the range of leaks that may occur from the different equipment items present within the facility. Following assessment of incident consequence, events are carried forward for frequency analysis and assessment of the risk level to facility personnel and to the public. Incident frequencies are derived for the various scenarios using appropriate historical release frequency and ignition probability data.

12.5 Safety Risk Assessment Results

12.5.1 Gas Processing Plant and Storage and Loading Area

A high-level risk analysis study has been carried out for the onshore gas processing plant by Shell Global Solutions. The risk analysis focused on those events shown to have off-site impacts or potential to escalate and cause off-site impacts and evaluated risk in terms of individual fatality risk, which is the risk of death to a person at a given location exposed to the hazard 24-hours of the day and 365 days in the year. A detailed Quantitative Hazard and Risk Assessment of the Development will be prepared as the design progresses.

IRPA levels for on-site personnel will satisfy the 1×10^{-3} Woodside corporate acceptance criteria. The gas processing modules contribute the greatest risk to life over the project lifecycle.

The gas processing plant and adjacent storage and loading area is located in an industrial area well away from residential areas. The majority of hazardous scenarios are fires or explosions that are essentially localised within the gas processing plant. Risk levels at the storage and loading area are lower than the main gas processing plant due to the limited number of equipment items and release sources. The LNG storage tanks will be of the full containment type with inner and outer tanks both designed to contain the LNG liquid and so reducing the potential for an external spill to negligible levels. The condensate tanks will be of the floating roof type and will be located within bund walls designed to fully contain the contents of a tank in the event of a spill. Fire protection systems will be provided at the storage tanks and at the jetty to control potential fire events and prevent escalation. As a result of these design measures, the effects of a fire will be localised in their potential impact on people and the fire consequence distances would not be expected to impact off-site.

Risk contours for off-site risks are shown in **Figure 12-1** and **Figure 12-2**. The $50x10^{-6}$ and $10x10^{-6}$ contours are contained within the site boundaries, so the EPA criteria for boundaries of an industrial site and buffer zones for active open spaces are met. In keeping with Woodside's commitment to minimise risk levels to operating personnel and the public to ALARP, ongoing attempts will be made to reduce these risk contours during the detailed design phase.

There are no other hazardous facilities immediately adjacent to the onshore facilities. Other industrial facilities in the area include Burrup Fertiliser's Ammonia Plant to the south-east, Karratha Gas Plant to the north and Dampier Port Authority to the south. These facilities are at an adequate distance from the Pluto LNG Development sites to have any significant impact on cumulative risks.

Table 12-2 Principal Safety Risk Contributors

Project Phase	Task	Risks Identified
Design	Surveying	Vessel collision/accident Occupational risk
Construction	Offshore vessel mobilisation/demobilisation Offshore facilities fabrication and installation	Construction site accident - occupational risk
	Pipelay activities	Vessel collision/accident Occupational Risk
	Well drilling	Hydrocarbon leak/fire/explosion Construction site accident - occupational risk
	Onshore facilities fabrication and installation	Blasting Construction site accident - occupational risk
Operation	Offshore platform	Hydrocarbon leak/fire/explosion Transportation (e.g. helicopter) Structural (e.g. ship collision) Occupational risk
	Subsea facilities	Maintenance and intervention activity incident – loss of hydrocarbon containment Occupational risk
	Pipelines	Hydrocarbon leak
	Supply vessel operations	Extreme weather Occupational risk
	Onshore facilities	Process operations Hydrocarbon leak/fire/explosion LNG and Condensate tanker loading Occupational risk
	LNG and condensate transport	Hazardous material transport Shipping accidents/collisions
Decommissioning	Onshore facilities	Occupational accidentsHazardous material management
	Well decommissioning	Loss of well containment Occupational risk

12.5.2 LNG and Condensate Export

It is anticipated that the frequency of LNG vessel exports will be once every five days. Condensate exports will be very infrequent, with exports anticipated to occur four times a year. During operation, up to four support tugs will be required to safely assist tankers during approach and departure operations. All vessels will be under the control of a local pilot and under radar surveillance from the Dampier Port Authority. Management procedures are in place for preventing major vessels from coming within one nautical mile of each other. The risk associated with shipping LNG and condensate is therefore very low.

12.5.3 Offshore Platform

The offshore platform and subsea facilities are described in **Section 4.5.2**.

As the design progresses quantitative risk assessment will be developed to ensure that the offshore facilities will satisfy the 1 x 10^{-3} Woodside corporate acceptance criteria for IRPA levels and that risks are minimised to ALARP. The offshore facilities will be the subject of a full and rigorous Safety Case approval process. Due to the remote location of the offshore infrastructure, there will negligible risk to the public.

12.5.4 Emergency Response Planning

At this stage in the Development, detailed emergency plans and procedures have not been formulated. These will be developed in conjunction with the appropriate civil and maritime authorities during detailed engineering to ensure that all the appropriate operational procedures are in place, and the necessary facilities available, before commissioning of the gas processing plant.

Figure 12-1 Pluto LNG Plant Risk Contours (Site B)

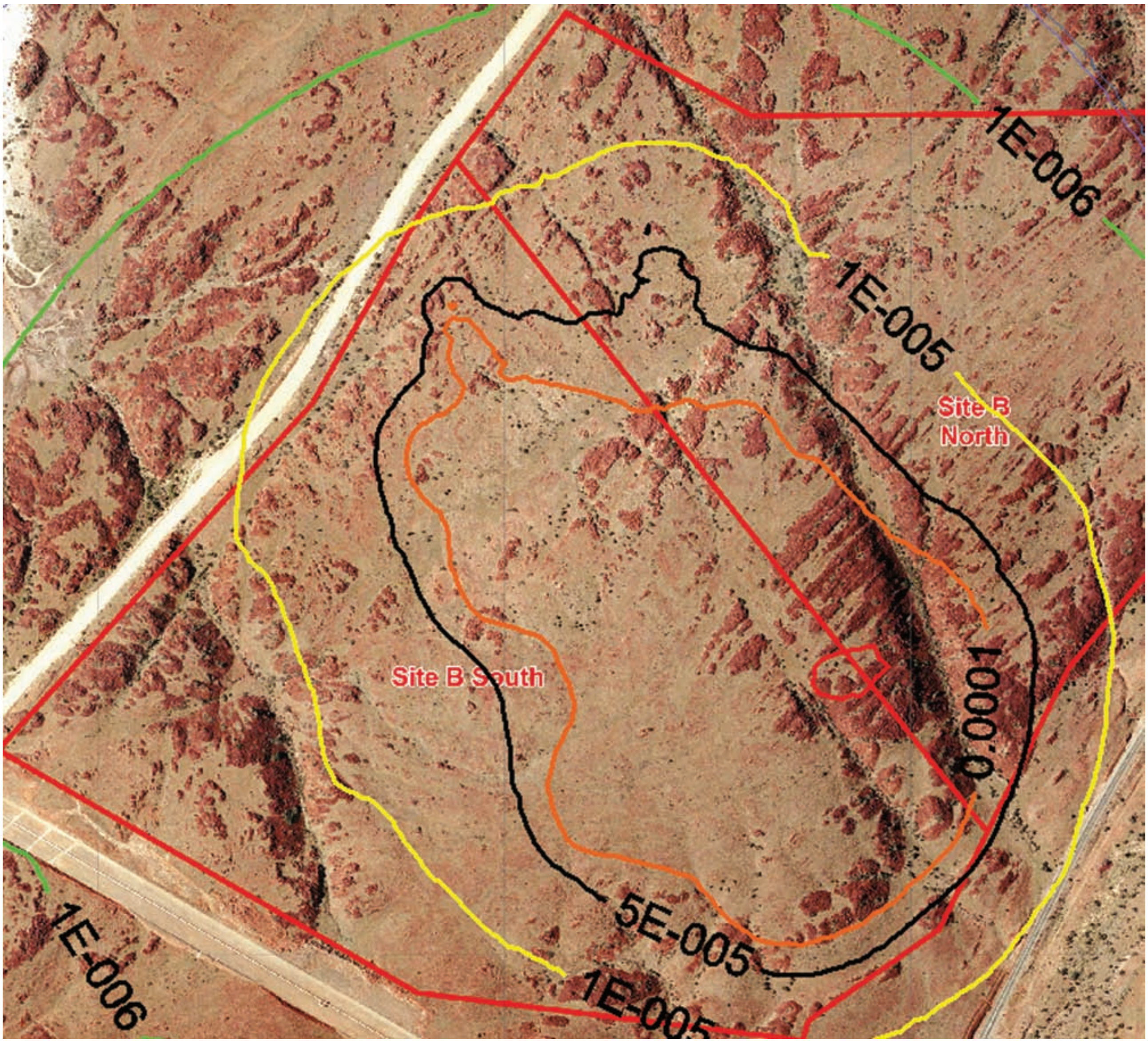
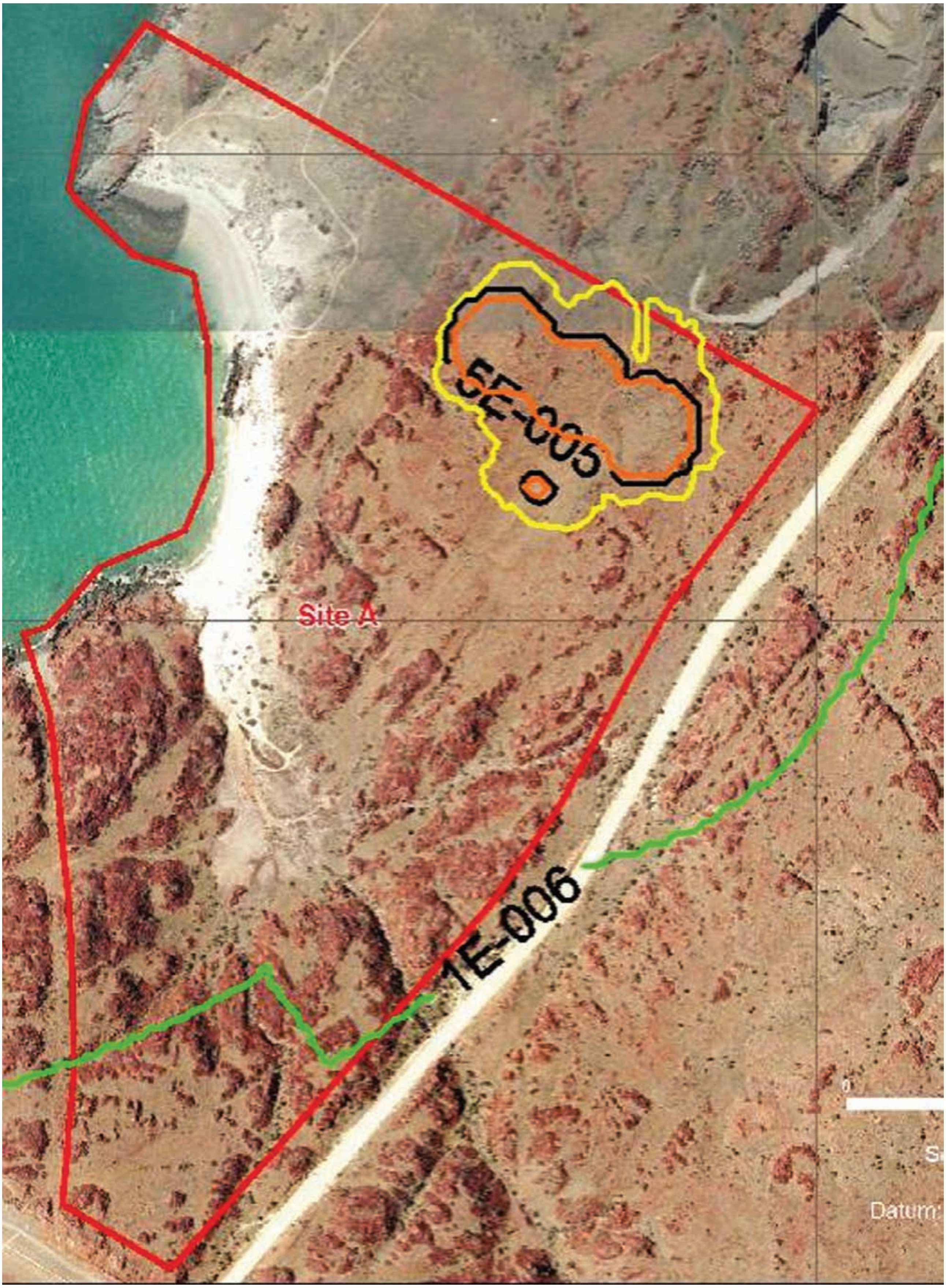


Figure 12-2 Pluto Storage and Loading Area Risk Contours (Site A)



Environmental Management

13

13.1 Environmental Management Programme

Preventative and management measures will be applied throughout the life of the Pluto LNG Development to ensure that significant environmental impacts associated with the proposed Development are avoided or minimised.

The measures are consistent with Woodside's Environmental Policy (**Appendix A**) which seeks to ensure that planning and performance of company activities are undertaken to either avoid adverse impacts or keep them to as low as reasonably practicable (ALARP). The Policy is applied to Woodside's activities and is based on the principle of continuous improvement. A Woodside HSE–Management System will also be developed and implemented.

An internal Register of Environmental Hazards has been developed during project planning to identify environmental issues and ensure issues are addressed, along with other business priorities, in the early screening and design stages. Progress will continue to be periodically reviewed and documentation updated during project design and execution.

Environmental performance issues relevant to contractors will be managed through the requirements of Woodside's tendering and contracting procedures. Environmental performance forms part of Contractor and Supplier selection. This process is outlined in the Procurement and Logistics Supply Chain Management System. Contract Sponsors are designated for every contract, and are responsible for activities in the contracting process and for contract execution. The Woodside Contract Sponsor ensures the contractor has appropriate systems in place to manage their Health, Safety and Environmental (HSE) risks. Contractors must have an Environmental Management Plan (EMP) that is acceptable to Woodside before any work can commence. Contractor mobilisation must be conditional upon receipt of an acceptable EMP based on the level of environmental risk.

The following measures will also be implemented to ensure a high level of environmental performance:

- auditing of compliance including corrective actions
- workshops and inductions for staff and contractors focussed on HSE management and performance
- presence of onsite HSE representative during construction activities.

Employees involved in the various activities associated with the proposed Development will undertake HSE inductions, which will involve input from professional HSE staff.

Detailed EMPs and Environment Plans (EPs) will be prepared to regulatory agency requirements for activities identified as potentially impacting on the environment.

13.2 Environmental Management Plans

Environmental aspects of the Pluto LNG Development will be managed primarily through the development and implementation of EPs and EMPs. The purpose of these plans is to identify potential and actual environmental aspects and impacts of all development phases, onshore and offshore, including:

- drilling
- installation, construction and commissioning
- production
- decommissioning.

The plans also describe or reference the procedures and equipment proposed to prevent, monitor and manage possible effects, and will include monitoring programmes. All plans will be drawn up in accordance with the Pluto LNG Development management actions presented in **Table 13-1**.

Offshore EPs follow different requirements to onshore EMPs as the former are drawn up in accordance with the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999. An outline of the requirements of offshore EPs is provided in **Appendix F**. Detailed EPs will cover drilling, installation, production and decommissioning phases of the Development. A Marine Pest Management Plain will also be developed for applicable phases of the Development.

A detailed Dredging and Spoil Disposal Management Plan (DSDMP) will also be developed separate to the Draft PER which will provide the framework for the proposed capital dredging programme to ensure that it is implemented with minimal environmental impact. The framework DSDMP is provided in **Appendix I**.

The EMPs governing onshore activities are structured differently from the offshore EPs. The following individual framework EMPs have been developed to address onshore and nearshore impacts during the construction phase and will be included in a Construction Environmental Management Plan:

- Sea Turtle Management Plan
- Waste Management Plan
- Noise Management Plan
- Blasting Management Plan
- Erosion and Sediment Control Management Plan
- Groundwater and Surface Water Protection Plan
- Onshore Spill Response Plan
- Terrestrial Vegetation and Flora Management Plan
- Terrestrial Fauna Management Plan
- Weed Management Plan
- Dust Management Plan
- Cultural Heritage Management Plan
- Traffic Management Plan
- Rehabilitation Management Plan.

Framework EMPs that will be developed specifically for the operation phase will include: the Waste Water Management Plan, Social Impact Management Plan and Greenhouse Gas Management Plan. These Framework EMPs will be consolidated in an Operation Environmental Management Plan (OEMP). Many of the plans developed for the construction phase will be amended for the operations phase, including the following:

- Waste Management Plan
- Noise Management Plan
- Groundwater and Surface Water Protection Plan
- Onshore Spill Response Plan
- Terrestrial Fauna Management Plan
- Weed Management Plan.

The framework for each plan is given in **Appendix G**; the proposed management measures outlined in **Sections 7, 9** and **11** have been incorporated into these plans. The framework plans will be developed further in accordance with the anticipated Development schedule, once detailed design information is available and the construction contractors are commissioned.

A consolidated overarching EMP document will be developed to combine the individual onshore/nearshore EMPs, in accordance with recognised standards and applicable Commonwealth and Western Australian state legislation. The consolidated EMP will be submitted to the relevant authorities for approval prior to construction. Upon the commencement of the Development, the EMPs will be reviewed according to a regular timeframe and updated if necessary.

13.3 Monitoring Programmes

Specific environmental monitoring programmes for the offshore/marine and onshore components of the Pluto LNG Development will be undertaken. The monitoring programmes will be outlined in detail within the EPs and EMPs and will include:

- information needed to provide a suitable baseline for subsequent monitoring
- the types of impacts that are likely to need monitoring
- the ecosystems parameters to be monitored
- the timing and frequency of monitoring
- policies for evaluating and amending the monitoring programme.

Once detailed design information is available for the proposed Development, the monitoring programme will be finalised and submitted to relevant government agencies with the respective EPs and EMPs. A Framework Marine and Intertidal Monitoring Programme is presented in **Appendix J**.

13.4 Management Actions

Woodside is committed to achieving or exceeding a level of environmental management and performance consistent with national and international standards and statutory obligations. The most economically effective, environmentally sound technology and procedures will be incorporated into the design of the Development in accordance with the ALARP principle.

The proposed Pluto LNG Development will be undertaken in a manner that will minimise impacts on the surrounding biophysical and social environments. Accordingly, management actions have been nominated throughout the Draft PER and are summarised in **Table 13-1**.

Table 13-1 Summary of Proposed Draft Management Actions

Actions No.	Topic	Action	Objective	Timing	Advice from
Stakeholder Engagement					
1	Stakeholder Engagement	Woodside will undertake ongoing liaison with the local community.	To establish a working relationship with community members such that environmental and social impacts arising from the Development are minimised.	Ongoing	
Environmental Management					
2	Environmental Management System	Develop and implement an **Environmental Management System**.	To manage and minimise environmental impacts and continually improve environmental performance.	All phases	
3	Construction Environmental Management	Develop and implement a **Construction Environmental Management Plan** for onshore/nearshore activities and **Environment Plans** for offshore activities. This will consist of a series of management plans that will include: sea turtles; waste; noise; blasting; erosion and sediment control; ground water and surface water protection; onshore spill response; terrestrial vegetation and flora; terrestrial fauna; weeds; dust; cultural heritage; traffic; social impact; and rehabilitation. These plans will include measures to ensure that construction personnel are properly inducted and that an auditing system is in place to vet implementation of plans.	To manage all relevant environmental factors associated with construction of the proposed development. Minimise environmental impact. Continually improve environmental performance. Ensure all construction personnel are aware of their responsibilities to ensure compliance with management plans.	Prior to construction	Environmental Protection Authority (EPA) Department for the Environment and Heritage (DEH) Department of Environment and Conservation (DEC) Main Roads WA (MRWA) Department of Indigenous Affairs (DIA) Shire of Roebourne
4	Operation Environmental Management	Develop an **Operation Environmental Management Plan**. This will consist of a series of management plans that will include consideration of: waste water; waste; noise; groundwater and surface water protection; weeds; onshore spill response; terrestrial fauna; greenhouse gases; social impacts; cultural heritage. These plans will include measures to ensure that operational personnel on-site are properly inducted and that an auditing system is in place to vet implementation of plans.	To manage all relevant environmental factors associated with operation of the proposed development. Ensure all operational personnel are aware of their responsibilities to ensure compliance with management plans.	Prior to commissioning	EPA DEH DEC DIA Shire of Roebourne
5	Decommissioning Environmental Management	Develop and implement a **Decommissioning Plan**.	To manage and/or minimise environmental impacts associated with decommissioning.	Prior to decommissioning	EPA DEC Shire of Roebourne DEH
6	Inductions	Personnel working on site (either offshore or onshore) will undertake environmental and cultural heritage inductions before commencing site work.	To manage and minimise environmental impacts.	All phases	
7	Environmental Performance	Ensure a high level of environmental performance by: • auditing of compliance including corrective actions • workshops and inductions for staff and contractors focussed on HSE management and performance • presence of onsite HSE Representative during construction activities.	To manage and minimise environmental impacts.	All phases	

Terrestrial Environment					
8	Terrestrial Fauna Protection	Prepare and implement a **Terrestrial Fauna Management Plan** (**Table G-12**, **App. G**). Impacts will be minimised by implementing the following measures: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Traffic is kept to designated tracks and drivers will abide by the allocated speed limit to minimise fauna fatality or injury by moving vehicles. • Measures will be in place to protect the Pilbara olive python, including relocation of Pilbara olive pythons found during earthworks by trained handlers.	To minimise impacts on terrestrial fauna and habitats. To minimise impacts on fauna species of conservation significance. To minimise death of fauna as a result of vehicle strike. To prevent the spread of introduced species.	Construction and operation	DEC DEH
9	Vegetation and Flora Protection	Prepare and implement a **Terrestrial Vegetation and Flora Management Plan** (**Table G-11**, **App. G**) that includes the following: • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • Vegetation communities of conservation significance in proximity to working areas will be clearly marked and access to these areas will be prohibited. • Access for vehicles and machinery will be along designated access tracks and parking areas. • The DEC will be consulted regarding the development of suitable management procedures for Priority flora.	To minimise the amount of vegetation that is permanently cleared. To minimise the effects of construction on Priority flora species. To prevent disturbance of vegetation and flora adjacent to work areas.	Construction	DEC
10	Weeds	Prepare and implement a **Weed Management Plan** (**Table G-13, App. G**) that includes the following: • Establishing and maintaining plant, vehicles and equipment hygiene to prevent introduction and transfer of weeds. • Monitoring weeds during site preparation works/construction and operations. • Implementing weed control methods to manage any new weed infestations during construction and operations, where they can be effectively controlled.	To minimise the introduction and spread of weed species.	Construction and operation	DEC

11	Rehabilitation	Prepare and implement a **Rehabilitation Management Plan** (**Table G-17**, **App. G**) that will include the following: • Rehabilitation and stabilisation will be undertaken following completion of the construction activities. • Vegetative matter and topsoil cleared from the working areas will be stockpiled for use in rehabilitation.	To maximise rehabilitation success, by: • Minimising the effects of vegetation clearance. • Ensuring that the area is suitably rehabilitated with reference to the control of erosion and sedimentation.	Construction and decommissioning	DEC
12	Erosion and Sedimentation	Prepare and implement an **Erosion and Sediment Control Management Plan** (**Table G-8**, **App. G**) that will include the following: • The total area to be disturbed will be restricted to the minimum area required for the Development. • Runoff control measures will be implemented. • Sediment/silt fences will be installed to trap sediment runoff downstream of construction areas. • Erosion and sediment control structures will be routinely inspected and maintained to ensure they remain effective, including the removal of accumulated silt as required.	To minimise soil disturbance, degradation and erosion.	Construction	DEC Commissioner for Soil and Land Conservation
13	Groundwater and Surface Water	Prepare and implement a **Groundwater and Surface Water Protection Management Plan** (**Table G-9**, **App. G**) that will include the following: • A hierarchal drainage water management system is designed to segregate clean water and treat potentially contaminated water. • Strict storage procedures will be maintained for environmentally hazardous materials. • The use of water for hydrotesting, dust suppression, potable supplies is correctly permitted and approved.	To maintain the existing quality of water resources. To minimise the potential for ground and surface water contamination. To minimise pressure on existing water resources.	Construction and operation	DEC Water Corporation Department of Water
14	Acid Sulfate Soils	Should detailed geotechnical investigations and additional desktop investigations identify Acid Sulphate Soils (ASS), a site investigation will be conducted to consider the specific location or locations of disturbance; the nature of disturbance; volume of material to be disturbed and maximum depth of disturbance.	To determine presence of ASS before construction.	Prior to construction	DEC

Marine Environment					
15	Sea Turtle Protection	Prepare and implement a **Sea Turtle Management Plan** (**Table G-1, App. G**) that will include the following: • Minimising lighting to ALARP in nearshore areas while maintaining safe construction and operating conditions. • Minimising light spill, particularly where white lights, such as fluorescent lights are used.	To minimise the impact of blasting activities, vessel movements, permanent structures and lighting on turtles including nesting and hatchling activity.	Construction	DEC DEH
16	Drilling	Prepare and implement a **Drilling Environment Plan**.	To manage environmental impacts during drilling and minimise the potential for sediment and water quality reduction and subsequent impacts on biota.	Drilling	DoIR
17	Waste Water	Prepare and implement a **Waste Water Management Plan** (**Table G-3, App. G**) that will include the following: • The residual total hydrocarbon in water concentration of waste water discharge will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound. • Pluto treated waste water composition will be determined and Whole Effluent Toxicity (WET) testing will be undertaken as soon as first water becomes available and periodically thereafter. • Monitoring will confirm that a high level of ecological protection is being achieved at the edge of the agreed mixing zone. The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily. • A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms – this will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary.	To comply with applicable legislation and guidelines. Minimise the potential for adverse impacts on water quality.	Operation	DEC DEH
18	Anti-fouling	Construction and/or operation vessels to adhere to complete prohibition on the presence of TBT paints on ships by 1 January 2008	To minimise the impact on marine organisms and comply with IMO regulations.	All phases	
19	Marine Pests	Prepare and implement a **Marine Pest Management Plan** (**Table G-2, App. G**) that will include the following; application of the *Quarantine Act 1908* and Regulations 2000 (Cwth) and the AQIS ballast water management requirements for international shipping (July 2001); a compulsory requirement for all vessels entering or leaving Australian waters.	To minimise introduction of introduced species and contamination of marine waters.	All phases	AQIS DEH

20	Hydrotest Water	A **Pipeline Flooding and Hydrotesting Procedure** and a **Pipeline Pre-commissioning Procedure** will be developed – prior to implementation, an Environment Plan covering flooding, hydrotesting and pre-commissioning activities will be submitted to the regulatory authority for review and approval.	To minimise the potential for water quality reduction and subsequent impacts on marine and terrestrial environment.	Commissioning	DoIR
21	Dredging	Prepare and implement a **Dredging and Spoil Disposal Management Plan** (**App. I**).	To manage direct and indirect environmental impacts during dredging and dredge spoil disposal.	Dredging phases	DEH, DEC, DPA
Emissions					
22	Greenhouse Gas Emissions	Develop and implement a **Greenhouse Gas Management Plan** (**Table G-5, App. G**) that includes the following: • Ensure greenhouse gas and energy efficiency of design by inclusion of greenhouse gas emissions in all key design decisions and technology selections where relevant. • Ensure efficient operation of the Pluto LNG Development by: • Minimising venting and flaring of hydrocarbons and fuel gas consumption by using procedural solutions to reduce venting, flaring and combustion of hydrocarbons to as low as reasonably practicable. • Minimising releases by ensuring equipment is correctly maintained.	To reduce venting, flaring and combustion of hydrocarbons to as low as reasonably practicable.	Prior to operation	DEC
23	Combustion Products	Flaring events will be minimised to ALARP.	To reduce flaring and combustion of hydrocarbons to as low as reasonably practicable.	Operation	DEC
24	Dust Control	Prepare and implement a **Dust Management Plan** (**Table G-14, App. G**) that includes the following: • The area disturbed will be the minimum required for construction. • Exposed surfaces such as stockpiles and cleared areas, and the duration that these areas are exposed, will be minimised. • Dust suppression techniques and/or watering of unsealed roads, access routes, exposed ground surfaces and stockpiles will be implemented. • Rehabilitation of vegetation will be undertaken in temporarily disturbed areas to minimise dust generation.	To ensure that the effects of dust generation on the environment and communities are minimised.	Construction	DEC

25	Noise	Prepare and implement a **Noise Management Plan** (**Table G-6, App. G**) that will include the following: • Consideration of measures such as low noise air-cooling fans and acoustic lagging on compressor suction, discharge and recycle piping. • Noise levels from flaring are below the Woodside absolute standard for noise emissions of 115 dB(A) at ground level.	To minimise the impacts of noise on the amenity of the surrounding areas.	Construction and operation	DEC
26	Vibration	Prepare and implement a **Blasting Management Plan** (**Table G-7, App. G**) that will include the following: • Smaller, more frequent blasts will be planned using sequential explosive charges to minimise cumulative impacts of the explosions. • Use of sirens and signage to inform construction personnel and members of public that blasting will take place. • Public access to the beach at Site A will be restricted during blasting activities. Warning signs will be placed on the beach, and an observer will monitor the beach from a safe location (either on the beach or a nearby boat) to prevent boats landing or to stop blasting until the beach is cleared.	To ensure the safety of construction personnel and members of the general public during blasting operations. To minimise the noise and vibration impacts associated with blasting. To minimise impacts to terrestrial and marine fauna.	Construction	DEC
27	Waste	Prepare and implement a **Waste Management Plan** (**Table G-4, App. G**) for discrete phases of the Development that includes the following: • Inductions will provide details on waste management requirements for all waste streams. • Implementation of waste hierarchy: reduce, reuse, recycle and recover waste. • Waste reduction at source will be included in tenders for supply and construction contractors. • All hazardous waste materials will be documented and tracked, segregated from other waste streams and stored in suitable containers.	To minimise impacts on existing waste facilities. To minimise environmental impacts associated with waste generation and accidental spills. To maximise waste reduction, recycling, reuse and recovery.	Construction, operation and decommissioning	DEC Shire of Roebourne

Non-Routine Discharge					
28	Onshore Spills	Prepare and implement an **Onshore Spill Response Plan** (**Table G-10, App. G**) that will include the following: • Site inductions will include correct materials handling procedures, spill management and spill response procedures. • Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations.	To reduce the risk of accidental spills occurring and ensure effective management measures are deployed in the event of a spill. To minimise the potential for water quality reduction and subsequent impacts on marine and terrestrial biota. To minimise impacts on soils, surface and ground water.	Construction and operation	DEC
29	Offshore and Nearshore Spill Contingency Planning	Drilling and construction activities will be carried out either under the umbrella of oil spill contingency arrangements in Woodside's region-wide Emergency Response Plan (ERP 3210) or a stand-alone plan that will require government approval. For the operational aspects of the Development, two options are under consideration: • Prepare a stand alone **Oil Spill Contingency Plan**. The plan will: – ensure effective and timely management of spills of hydrocarbons – describe the procedures to deal with an oil spill – define the roles, responsibilities of response personne – be separately assessed by DoIR under the P(SL)A and must be accepted prior to commencement of operations. • Tie-in to the existing regional Oil spill Contingency Plan.	To prevent hydrocarbon spills and ensure suitable recovery and response controls are in place.	All phases	DEC DoIR DPA

Social and Economic Environment					
30	Social Impacts	In consultation with local groups prepare and implement a **Social Impact Management Plan**.	To minimise impacts on stakeholders and the community.	Operation	
31	Cultural Heritage	Prepare and implement a **Cultural Heritage Management Plan** (**Table G-15, App. G**) that will include the following: • Disturbance to sites will be minimised as far as possible – where disturbance to site cannot be avoided, archaeological material will be relocated to designated conservation areas wherever practicable. • Any proposed disturbance to cultural heritage sites will be subject to a Section 18 Application under the *Aboriginal Heritage Act 1972* (WA). • Any archaeological discoveries during site preparation work will be reported to the regulatory authority in accordance with reporting and mitigation measures identified in the Cultural Heritage Management Plan, state government policy and the expectations of the Indigenous groups. • Access to conservation areas by Indigenous group will be maintained, subject to operational and occupational health and safety constraints.	To identify, record and assess the significance of all Aboriginal heritage sites. To provide the relevant Aboriginal community and organisations with information about the proposed Development and its potential impacts. To minimise impacts on Aboriginal heritage. To avoid disturbing cultural heritage sites. To protect cultural heritage and prevent disturbance of heritage sites.	Construction	DIA
32	Traffic Control	Prepare and implement a **Traffic Management Plan** (**Table G-16**, **App. G**) that will include the following: • Identifying construction periods which will result in lessened impact on existing public road network traffic. • Assessing of intersections suitable for the movement of pre-assembled units and advice on the required changes to accommodate these.	To ensure site traffic is managed in such a way so as not to adversely impact on the community, road users and sensitive habitats. To minimise dust generation through traffic movements.	Construction	MRWA Shire of Roebourne

Shortened Forms and Glossary

14

14.1 Shortened Forms

Term	Definition
°	Degree(s)
°C	Degree(s) Celsius
"	Inches
%	Percent
µg/cm	Microgram(s) Per Centimetre
µg/L	Microgram(s) Per Litre
µg/m	Microgram(s) Per Metre
µg Sn/kg	Microgram of Tin (found in TBT paints) Per Kilogram
µm	Micrometer(s)
3D	Three Dimensional
4WD	Four Wheel Drive
A$	Australian Dollars
AASS	Actual Acid Sulphate Soils
ABS	Australian Bureau of Statistics
ACHM	Australian Cultural Heritage Management Pty Ltd
ACMC	Aboriginal Cultural Material Committee
AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AGRU	Acid Gas Removal Unit
AHD	Australian Height Datum
AIMS	Australian Institute of Marine Science
ALARP	As Low As Reasonably Practical - a standard for risk reduction Formal demonstration of ALARP is required within HSE Cases or in Environmental Plans required under the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999.
aMDEA	Activated Methyl Diethonolamine
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Association
ANZECC	Australia and New Zealand Environment and Conservation Council
AOC	Accidentally Oily Contaminated (water)
APASA	Asia-Pacific Applied Science Associates
APPEA	Australian Petroleum Production and Exploration Association
AQIS	Australian Quarantine and Inspection Service
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS	Australian/New Zealand Standard
ASS	Acid Sulfate Soils
BAMIEA	Burrup and Maitland Industrial Estates Agreement
BOM	Bureau of Meteorology
bpd	Barrels Per Day
BPMAB	Burrup Peninsula Management Advisory Board

BPP	Benthic Primary Producer
BPPH	Benthic Primary Producer Habitat
BTEX	Benzene, Toluene, Ethylbenzene and Xylene (volatile organic compounds)
C5+	Pentane Plus
$CaCl_2$	Calcium Chloride
CALM	Western Australian Department of Conservation and Land Management (now the Department of Environment and Conservation)
CAMBA	China Australia Migratory Bird Agreement
CCTV	Closed-Circuit Television
CCD	Current Coral Distribution
CD	Chart Datum
CDF	Canadian Department of Fisheries
CH_4	Methane
CHL	Current Historical Loss
CHMP	Cultural Heritage Management Plan
cm/s	Centimetre(s) Per Second
CMS	The Convention on the Conservation of Migratory Species of Wild Animals
CO	Carbon Monoxide
CORMIX	Cornell Mixing Zone Expert System
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CO_2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CSIRO	Commonwealth Science and Industrial Research Organisation
Cwth	Commonwealth
dB	Decibel
dB (A)	Decibel with 'A' Weighting
dB re 1μPa	Energy level for sound pressure levels
dB re $1μPa^2/Hz$	Energy level for sound pressure levels over a specified frequency
DEC	Department of Environment and Conservation
DEH	Commonwealth Department of the Environment and Heritage
DEM	Digital Elevation Model
DFWA	Department of Fisheries (Government of) Western Australia
DIA	Department of Indigenous Affairs
DNA	Deoxyribonucleic Acid
DoE	Department of Environment (now the Department of Environment and Conservation)
DoIR	Department of Industry and Resources
Domgas	Domestic Gas
DPA	Dampier Port Authority
DPI	Department for Planning and Infrastructure
DSDMP	Dredging and Dredge Spoil Disposal Management Plan
EC	Electrical Conductivity
e.g.	For example
EOM	Extractable Organic Matter
EMP	Environmental Management Plan
ENM	Environmental Noise Model
EPs	Environment Plans
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986* (Western Australia)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)

ERP	Emergency Response Plan
ERS	Environmental Risk Solutions
FESA	Fire and Emergency Services
FWKO	Free Water Knock Out
g/L	Gram(s) per Litre
g/m^2	Gram(s) per Metre Squared
$g/m^2/day$	Gram(s) per Metre Squared Per Day
$g/m^2/month$	Gram(s) per Metre Squared Per Month
$g/m^2/yr$	Gram(s) per Metre Squared Per Year
g/s	Gram(s) per Second
GEHA	Government Employee Housing Association
GIS	Geographic Information Systems
$g\ m^{-2}\ d^{-1}$	Gram(s) per Metre Squared per Day
GWP	Global Warming Potential
H_2S	Hydrogen Sulfide
ha	Hectare(s)
HCD	Historical Coral Distribution
HOCNF	Harmonised Offshore Chemical Notification Format
hr	Hour(s)
HSE	Health, Safety and Environment
HWM	High Water Mark
Hz	Hertz
IALA	International Association of Lighthouse Authorities
ICOMOS	International Council on Monuments and Sites
ID	Identification
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
IRPA	Individual Risk Per Annum
ISDN	Integrated Services Digital Network
IUCN	International Union for the Conservation of Nature
JAMBA	Japan Australia Migratory Bird Agreement
KCl	Potassium Chloride
kg	Kilogram(s)
kg/l	Kilogram(s) Per Litre
$kg/m^2/month$	Kilogram(s) Per Metre Squared Per Month
kg/m^3	Kilogram(s) Per Metre Cubed
kg/yr	Kilogram(s) Per Year
kl	Kilolitre(s)
km	Kilometre(s)
km^2	Kilometre(s) Squared
km/hr	Kilometre(s) Per Hour
kPaG	Kilopascal Gauge
kW	Kilowatt(s)
l	Litre(s)
l/s	Litre(s) per second
LA_{Max}	LAMax assigned noise level means a noise level which is not to be exceeded at any time.
LA_1	LA1 assigned noise level which is not to be exceeded for more than 1% of the time.
LA_{10}	LA10 assigned noise level which is not to be exceeded for more than 10% of the time.
LAT	Lowest Astronomical Tide

LC50	Lethal Concentration 50
LNG	Liquefied Natural Gas
LOS	Level of Service
LPG	Liquid Petroleum Gas
LWM	Low Water Mark
m	Metre(s)
m/s	Metre(s) Per Second
m^3	Metre(s) Cubed
m^3/day	Metre(s) Cubed Per Day
m^3/hr	Metre(s) Cubed Per Hour
m^3/yr	Metre(s) Cubed Per Year
m AHD	Metre(s) Australian Height Datum
MARPOL	International Convention for the Prevention of Pollution from Ships
mbgs	Metre(s) Below Ground Surface
MEG	Monoethylene Glycol
mg Chl-a/m^3	Milligram(s) Chlorophyll-a Per Metre Squared
mg/cm^2	Milligram(s) Per Centimetre Squared
mg/cm^2/d	Milligram(s) Per Centimetre Squared Per Day
mg/l	Milligram(s) Per Litre
mg/m^3	Milligram(s) Per Metre Cubed
MLA	Member of Legislative Assembly
MLC	Member of Legislative Council (WA)
mm	Millimetre(s)
Mm^3	Million Metres Cubed
mmbbl	Million Barrels (Oil Reserves)
MMRF	Monash Mulit-Regional Forecasting
MODU	Mobile Offshore Drilling Unit
MOF	Material Offloading Facility
mol %	Molar Percentage
MP	Member of Parliament
MRWA	Main Roads Western Australia
Mtpa	Million Tonnes Per Annum
N_2O	Nitrous Oxide; a colourless, odourless gas which is also known more commonly as laughing gas
NO_x	Oxides of Nitrogen; group of highly reactive gases which contain Nitrogen and Oxygen in varying amounts.
NaCl	Sodium Chloride
NDGC	National Geophysical Data Center
NDE	Non-Destructive Examination
NEPM	National Environment Protection Measure
NES	National Environmental Significance
NGO	Non Government Organisation
nm	Nautical miles
NODGDM	National Ocean Disposal Guidelines for Dredged Material
NOEC	No Effect Concentration
NORMS	Naturally Occurring Radioactive Material
NPV	Net Present Value
NRU	Nitrogen Rejection Unit
NSW	New South Wales
NT	Northern Territory

NWBM	Non Water Based Mud
NWSTF	North West Slope Trawl Fishery
NWSV	North West Shelf Venture
O_3	Ozone
OEMP	Operation Environmental Management Plan
OSCP	Oil Spill Contingency Plan
OSPARCOM	Oslo-Paris Commission
P_1	Primary Risk
P_2	Secondary Risk
P_3	Tertiary Risk
pa	Per Annum
PAH	Polycyclic Aromatic Hydrocarbons
PASS	Potential Acid Sulfate Soil
PDC	Pilbara Development Commission
PEC	Predicted Environmental Concentration
PER	Public Environment Report / Public Environmental Review
PFTIMF	Pilbara Fish Trawl (Interim) Managed Fishery
PHI	Predicted High Impact
PMI	Predicted Medium Impact
PM_{10}	Includes the smaller particles in the atmosphere (particulate matter), less than 10 micrometers in diameter.
$PM_{2.5}$	Particulate matter less then 2.5 microns in diameter
PNEC	Predicted No Effect Concentration
ppb	Parts per billion
ppm	Parts per million
PRRT	Petroleum Resource Rent Tax
P(SL)A	Petroleum (Submerged Lands) Act
PTMF	Pilbara Trap Managed Fishery
Pty Ltd	Propriety Limited
Qld	Queensland
ROV	Remote Operated Vehicle
RVP	Reid Vapour Pressure
SIA	Social Impact Assessment
SIMAP	Spill Impact Mapping and Assessment Program
SKM	Sinclair Knight Merz
SMFG	Size Managed Fish Grounds
SO_2	Sulfur Dioxide
SO_x	Oxides of sulfur; gases with varying amounts of sulfur and oxygen.
SOPEP	Ship-Board Oil Pollution Emergency Plan
sp.	Species (singular)
spp.	Species (plural)
SSIV	Subsea Isolation Valve
SST	Sea Surface Temperatures
STD	Subscriber Trunk Dialling
subsp.	Subspecies
TAFE	Technical and Further Education
TBT	Tri-butyl-tin
tcf	Trillion cubic feet
TDS	Total Dissolved Solids
tpa	Tonnes Per Annum

TPH	Total Petroleum Hydrocarbons
TSEP	Trunkline System Expansion Project
TSS	Total Suspended Solids
UK	United Kingdom
UKOOA	United Kingdom Offshore Operators Association
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
US$	United States Dollars
USA	United States of America
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
w/w	Weight to Weight
WA	Western Australia
WAMF	Western Australian Mackerel Fishery
WANCFS	Western Australian North Coast Shark Fishery
WAPC	Western Australian Planning Commission
WAXA	Western Australian Exercise Area
WBM	Water Based Mud
WET	Whole Effluent Toxicity
WestMAC	Western Trawl Fisheries Management Advisory Committee
WHO	World Health Organisation
Woodside	Woodside Energy Limited
WTBF	Western Tuna and Billfish Fishery
WWF	World Wildlife Fund

14.2 Glossary

Term	Definition
Ancillary Facilities	Supporting structures.
Aquifer	Layer of rock that holds water and allows water to percolate through it.
Australian Standard (AS)	An Australian Standard which provides criteria and guidance on design, materials, fabrication, installation, testing, commissioning, operation, maintenance, re-qualification and abandonment.
Ballast	Extra weight taken on to increase a ship's stability to prevent rolling and pitching. Most ships use seawater as ballast. Empty tank space is filled with inert (non-combustible) gas to prevent the possibility of fire or explosion.
Bathymetry	Related to water depth – a bathymetry map shows the depth of water at a given location on the map.
Benthos/Benthic	Related to the seafloor, and includes organisms living in or on the sediment/rocks on the seafloor.
Biodiversity	Relates to the level of biological diversity of an environment, or the variability among living organisms.
Biota	Collective terms for all the flora and fauna of a region or area.
Box Corer	A sediment sampling device typically used in deep-sea research.
Calcareous Conglomerate	A rock made of fragments of rocks and pebbles and cemented by calcium carbonate.
Calcrete	Soil cemented by calcium carbonate.
Caprock	An overlying rock layer that is more resistant to weathering than formations located beneath it.
Codes and Standards	Codes are requirements promulgated by industry groups and enforced by law. Standards are practices recommended by industry groups or individual companies that are regularly followed and are controlled by a process for reviewing and approving exceptions.
Colluvium	Loose sediments that accumulate at the base of a hill.
Condensate	Hydrocarbons that are gaseous in a reservoir but condense to form a liquid as they rise to the surface where the pressure is much less.
Cuttings	Inert pieces of rock, gravel and sand removed from the well during the drilling process.

Decibel (dB)	This is a measure of the overall noise level of sound across the audible spectrum with a frequency weighting (that is, 'A' weighting) to compensate for the varying sensitivity of the human ear to sound at different frequencies.
Dolerite	Medium grained igneous rock with composition similar to basalt. Usually found in dykes or sills.
Dredging	The deepening and/or widening of a waterway using a machine that removes materials be scooping or sucking the sediments.
Dyke	A tabular igneous intrusion that cuts across adjacent rock structures.
Environment	The surroundings of an organism including the other biota with which it interacts.
Environmental Management Plan	A procedure that identifies potential environmental impacts and methodologies necessary to mitigate them.
Epibenthic Sled	A semi-quantitative bottom-sampling device designed to trawl just above the bottom at the sediment water interface (the epibenthic zone). The sled occasionally (inadvertently) digs into the bottom, so an infaunal sample is also collected.
Ethnographic	Derived from scientific description and classification of the various cultural and racial groups of mankind.
Fauna	Collectively, the animal life of a particular region.
Ferromagnesian Laths	Minerals containing iron and magnesium in the shape of planks with one end sharpened.
Flaring	The process by which gas is burnt in a safe and controlled manner.
Flora	Collectively the plant life of a particular region.
Flowline	A pipe which allows flow to be contained between two places.
Gabbro	A dark, coarse grained igneous rock.
Gametes	Reproductive cells; eggs or sperms.
Geotechnical	Referring to the use of scientific methods and engineering principles to acquire, interpret, and apply knowledge of earth materials for solving engineering problems.
Granite	A coarse-grained igneous rock consisting of the following minerals: quartz, feldspar and very commonly mica.
Granophyre	Fine grained granitic material.
Greenhouse Gases	Emissions of gases such as carbon dioxide, methane, nitrous oxide that affect the radiation transfer through the atmosphere and significantly influence the greenhouse gas effect.
Grey water	Water resulting from washing or cooking.
Habitat	The specific place where a particular organism lives.
Hydrocarbons	A class of liquid, solids or gas organic compounds containing only carbon and hydrogen, the basis of almost all petroleum products.
HYDROMAP	Three-dimensional hydrodynamic model
Igneous	Rocks formed by the solidification of molten rock or magma.
Indonesian Throughflow	An ocean current that transports water between the Pacific Ocean and the Indian Ocean through the Indonesian Archipelago.
Invertebrate	Lacking a spinal column (for example, crabs, jellyfish).
Lithic	Pertaining to or consisting of stone.
Manifold	A pipe that has several lateral outlets to or from other pipes.
Methane	Odourless, colourless, flammable gas that consists of carbon and hydrogen and is a major past of natural gas.
Mitigation	Management measures which minimise and manage undesirable consequences.
National/International Standards	Published standards such as the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (includes sediment quality guidance) and the (Australian) National Environmental Protection Measures for Air Quality and Air Toxics.
Particulate Matter	Particles in the atmosphere; including: smoke, dirt, dust, spores, pollens, heavy metals and so on.
Pelagic	Living in the open sea (for example, fish that swim and feed in the open ocean, near the surface or well above the seabed).
pers. comm.	Personal communication.
Pigging	The process of inserting 'pigs' into a pipeline to remove deposits which could obstruct or retard flow through a pipeline. This process is during all phases in the life of a pipeline for many different reasons.
Pigs	Pipeline Integrity Gauge. A cylindrical device inserted into a pipeline to inspect the pipe or to sweep the line clean of water, rust or other foreign matter.
Pollution	Degradation or impairment of the purity of the environment by causing a condition that is hazardous to the public, safety, aesthetics, or welfare or to the biota.

Protected Species	Species considered rare, endangered, vulnerable or of restricted distribution and protected by specific national or international legislation; other species protected by specific national or international instruments, for example, migratory species, shore birds (JAMBA and CAMBA)
Proterozoic	Period in the Earth's history from 2.5 billion years ago to 540 million years ago.
Reservoir	A rock or formation which holds hydrocarbons within the pore spaces between individual grains.
Risk	The probability that a consequence will occur.
Safeguards	Preventative measures that reduce the likelihood of an event.
Screening Level	Level of a substance in the sediment below which toxic effects on organisms are not expected.
Shale Shakers	Vibrating screens used to separate cuttings from the drill muds.
Slugcatcher	A device that removes slugs of liquid from natural gas pipelines. Slugcatchers dissipate the energy of the liquid slugs that intermittently propagate through a gas pipeline.
Slugs	Liquids that can interfere with the proper operation of the pipeline and related equipment such as compressors, regulators, filters, meters and valves. The liquids normally found include hydrocarbon condensations, lubrication oils, produced water, and chemicals used in production, treatment, compression or dehydration of the gas.
SSFATE	Sedimentation process modelling system
Subsea Gathering System	Comprises infrastructure to collect and transfer reservoir fluids including subsea wells, manifolds and flowlines.
Terrestrial	The land as distinct from the water.
Topsoil	The upper layer of soil.
Trolling	Angling by drawing a baited line behind a moving vessel.
Turbidity	Measure of the clarity of a water body.
Void Ratio	The ratio of the volume of void space to the volume of solids of the soil
Well	A hole drilled into a hydrocarbon bearing reserve.
Zooplankton	Zooplankton are small, often microscopic, animals that generally follow the ocean currents, feeding on phytoplankton or other zooplankton. They are often the larval stages of larger marine animals, and typically include: Krill, copeopod, polychaete, amphipods and shrimp.

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15

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APPEA–see Australian Production and Exploration Association Limited.

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16

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The Woodside Group of Companies

Health and Safety Policy

General Policy Objectives

Woodside is an oil and gas exploration and production company. Our vision is to provide for society's energy needs in ways that make us proud. In this regard we believe that all injuries and industry related diseases are preventable and that striving continuously to improve our health and safety performance is fundamental to our business success.

We plan and perform our business activities to ensure that the risks of adverse effects on people are avoided or kept as low as reasonably practicable.

Strategies

To implement this Policy we will:

- Give health and safety prevailing status over other business objectives.
- Delay or stop activities where effective controls are not in place.
- Comply with all applicable laws and regulations, while aspiring to higher standards.
- Apply responsible standards where laws and regulations do not exist.
- Apply and demonstrate a systematic approach to health and safety management to ensure compliance and achieve continuous performance improvement.
- Set and regularly review health and safety objectives and targets.
- Monitor our performance and take action to address deficiencies.
- Openly communicate our health and safety performance with our workforce, Government and the wider community.
- Foster a culture that empowers and rewards everyone to act in accordance with this Policy.

Application

The Managing Director of Woodside Energy Ltd. is accountable to the Board of Directors for ensuring that this Policy is implemented. This Policy will be reviewed every three years.

This Policy applies to all personnel, contractors and joint venturers engaged in activities under Woodside's operational control. Responsible Woodside managers will use their influence to promote this Policy in non-operated ventures.

Don Voelte
Managing Director & CEO
April 2004

![WOODSIDE]

The Woodside Group of Companies

Environmental Policy

General Policy Objectives

Woodside is an oil and gas exploration and production company. Our vision is to provide for society's energy needs in ways that make us proud. While recognising that the world's hydrocarbon reserves are finite, we share the desire of the community to develop these resources in ways that meet the needs of the present, without compromising the environment for future generations.

At all stages of our business, we plan and perform activities so that adverse effects on the environment are avoided or kept as low as reasonably practicable.

Strategies

To implement this Policy we will:

- Delay or stop activities where effective environmental controls are not in place.
- Comply with all applicable laws and regulations while aspiring to higher standards.
- Apply responsible standards where laws and regulations do not exist.
- Apply and demonstrate a systematic approach to environmental management to ensure compliance and achieve continuous performance improvement.
- Set and regularly review environmental objectives and targets.
- Strive to prevent pollution, and seek improvement with respect to emissions, discharges, wastes, energy use, resource consumption and ecological footprint.
- Monitor the effects of our activities on the environment and take action to address effects where necessary.
- Openly communicate our environmental performance with our workforce, Government and the wider community.
- Foster a culture that empowers and rewards everyone to act in accordance with this Policy.

Application

The Managing Director of Woodside Energy Ltd. is accountable to the Board of Directors for ensuring this Policy is implemented. This Policy will be reviewed every three years.

This Policy applies to all personnel, contractors and joint venturers engaged in activities under Woodside's operational control. Responsible Woodside managers will use their influence to promote this Policy in non-operated ventures.

Don Voelte
Managing Director & CEO
April 2004

WOODSIDE

The Woodside Group of Companies

Indigenous Community Policy

Woodside believes enduring relationships with indigenous communities are necessary for our business success.

Objectives

Woodside establishes and maintains sustainable and mutually advantageous relationships with indigenous communities wherever it operates.

Woodside achieves this by:

1. Consulting relevant indigenous communities to promote an understanding of each other's concerns and aspirations;
2. Assisting indigenous communities to manage issues and challenges they face as a result of Woodside's activities;
3. Assisting indigenous people to compete effectively for employment within Woodside;
4. Seeking opportunities for indigenous communities to participate in Woodside's operations through commercially competitive, contractual and other cooperative ventures; and
5. Supporting partnerships that make a positive difference to indigenous communities.

Responsibilities

The Managing Director of the Woodside Group of Companies is accountable to the Board of Directors for ensuring this policy is implemented and that its effectiveness is reviewed annually.

Responsibility for the application of this policy rests with all Woodside employees and contractors.

Don Voelte
Managing Director & CEO
June 2005

Fish Species of Conservation Significance (EPBC Act)

B

Scientific Name	Common Name	Status	Type of Presence
Rhincodon typus	Whale Shark	Vulnerable, Migratory	Species or species habitat may occur within area
Acentronura larsonae	Helen's Pygmy Pipehorse	Listed Marine Species	Species or species habitat may occur within area
Bulbonaricus brauni	Braun's Pughead Pipefish, Pug-headed Pipefish	Listed Marine Species	Species or species habitat may occur within area
Campichthys tricarinatus	Three-keel Pipefish	Listed Marine Species	Species or species habitat may occur within area
Choeroichthys brachysoma #	Pacific Short-bodied Pipefish, Short-bodied Pipefish	Listed Marine Species	Species or species habitat may occur within area
Choeroichthys latispinosus	Muiron Island Pipefish	Listed Marine Species	Species or species habitat may occur within area
Choeroichthys suillus #	Pig-snouted Pipefish	Listed Marine Species	Species or species habitat may occur within area
Corythoichthys flavofasciatus	Yellow-banded Pipefish, Network Pipefish	Listed Marine Species	Species or species habitat may occur within area
Cosmocampus banneri	Roughridge Pipefish	Listed Marine Species	Species or species habitat may occur within area
Doryrhamphus dactyliophorus	Ringed Pipefish	Listed Marine Species	Species or species habitat may occur within area
Doryrhamphus excisus	Indian Blue-stripe Pipefish, Blue-stripe Pipefish	Listed Marine Species	Species or species habitat may occur within area
Doryrhamphus janssi #	Cleaner Pipefish, Janss' Pipefish	Listed Marine Species	Species or species habitat may occur within area
Doryrhamphus multiannulatus	Many-banded Pipefish	Listed Marine Species	Species or species habitat may occur within area
Doryrhamphus negrosensis	Flagtail Pipefish, Negros Pipefish	Listed Marine Species	Species or species habitat may occur within area
Festucalex scalaris	Ladder Pipefish	Listed Marine Species	Species or species habitat may occur within area
Filicampus tigris	Tiger Pipefish	Listed Marine Species	Species or species habitat may occur within area
Halicampus brocki	Brock's Pipefish	Listed Marine Species	Species or species habitat may occur within area
Halicampus grayi #	Mud Pipefish, Gray's Pipefish	Listed Marine Species	Species or species habitat may occur within area
Halicampus nitidus	Glittering Pipefish	Listed Marine Species	Species or species habitat may occur within area
Halicampus spinirostris	Spiny-snout Pipefish	Listed Marine Species	Species or species habitat may occur within area
Haliichthys taeniophorus #	Ribboned Seadragon, Ribboned Pipefish	Listed Marine Species	Species or species habitat may occur within area
Hippichthys penicillus #	Beady Pipefish, Steep-nosed Pipefish	Listed Marine Species	Species or species habitat may occur within area
Hippocampus angustus #	Western Spiny Seahorse, Narrow-bellied Seahorse	Listed Marine Species	Species or species habitat may occur within area
Hippocampus hystrix	Spiny Seahorse	Listed Marine Species	Species or species habitat may occur within area
Hippocampus kuda	Spotted Seahorse, Yellow Seahorse	Listed Marine Species	Species or species habitat may occur within area
Hippocampus planifrons	Flat-face Seahorse	Listed Marine Species	Species or species habitat may occur within area
Hippocampus spinosissimus	Hedgehog Seahorse	Listed Marine Species	Species or species habitat may occur within area
Micrognathus micronotopterus #	Tidepool Pipefish	Listed Marine Species	Species or species habitat may occur within area
Phoxocampus belcheri	Rock Pipefish	Listed Marine Species	Species or species habitat may occur within area
Solegnathus hardwickii	Pipehorse	Listed Marine Species	Species or species habitat may occur within area
Solegnathus lettiensis	Indonesian Pipefish, Gunther's Pipehorse	Listed Marine Species	Species or species habitat may occur within area
Solenostomus cyanopterus	Blue-finned Ghost Pipefish, Robust Ghost Pipefish	Listed Marine Species	Species or species habitat may occur within area
Syngnathoides biaculeatus	Double-ended Pipehorse, Alligator Pipefish	Listed Marine Species	Species or species habitat may occur within area
Trachyrhamphus bicoarctatus #	Bend Stick Pipefish, Short-tailed Pipefish	Listed Marine Species	Species or species habitat may occur within area
Trachyrhamphus longirostris	Long-nosed Pipefish, Straight Stick Pipefish	Listed Marine Species	Species or species habitat may occur within area

 # Also identified by Hutchins (2003)

Marine Reptile Species of Conservation Significance (EPBC Act)

C

Scientific Name	Common Name	Status	Type of Presence
Chelonia mydas	Green Turtle	Vulnerable, Migratory, Listed Marine Species	Species or species habitat may occur within area
Caretta caretta	Loggerhead Turtle	Endangered, Migratory, Listed Marine Species	Species or species habitat may occur within area
Dermochelys coriaceaa	Leathery Turtle, Leatherback Turtle	Vulnerable, Migratory, Listed Marine Species	Species or species habitat may occur within area
Eretmochelys imbricata	Hawksbill Turtle	Vulnerable, Migratory, Listed Marine Species	Species or species habitat may occur within area
Natator depressus	Flatback Turtle	Vulnerable, Migratory, Listed Marine Species	Species or species habitat may occur within area
Acalyptophis peronii	Horned Seasnake	Listed Marine Species	Species or species habitat may occur within area
Aipysurus apraefrontalis	Short-nosed Seasnake	Listed Marine Species	Species or species habitat may occur within area
Aipysurus duboisii	Dubois' Seasnake	Listed Marine Species	Species or species habitat may occur within area
Aipysurus eydouxii	Spine-tailed Seasnake	Listed Marine Species	Species or species habitat may occur within area
Aipysurus laevis	Olive Seasnake	Listed Marine Species	Species or species habitat may occur within area
Aipysurus tenuis	Brown-lined Seasnake	Listed Marine Species	Species or species habitat may occur within area
Astrotia stokesii	Stokes' Seasnake	Listed Marine Species	Species or species habitat may occur within area
Disteira kingii	Spectacled Seasnake	Listed Marine Species	Species or species habitat may occur within area
Disteira major	Olive-headed Seasnake	Listed Marine Species	Species or species habitat may occur within area
Emydocephalus annulatus	Turtle-headed Seasnake	Listed Marine Species	Species or species habitat may occur within area
Ephalophis greyi	North-western Mangrove Seasnake	Listed Marine Species	Species or species habitat may occur within area
Hydrelaps darwiniensis	Black-ringed Seasnake	Listed Marine Species	Species or species habitat may occur within area
Hydrophis czeblukovi	Fine-spined Seasnake	Listed Marine Species	Species or species habitat may occur within area
Hydrophis elegans	Elegant Seasnake	Listed Marine Species	Species or species habitat may occur within area
Hydrophis mcdowelli	N/A	Listed Marine Species	Species or species habitat may occur within area
Hydrophis ornatus	N/A	Listed Marine Species	Species or species habitat may occur within area
Pelamis platurus	Yellow-bellied Seasnake	Listed Marine Species	Species or species habitat may occur within area

Marine Mammal Species of Conservation Significance (EPBC Act)

D

Scientific Name	Common Name	Status	Type of Presence
Balaenoptera musculus	Blue Whale	Endangered, Migratory, Cetacean	Species or species habitat may occur within area
Megaptera novaeangliae	Humpback Whale	Vulnerable, Migratory, Cetacean	Species or species habitat may occur within area
Balaenoptera bonaerensis	Antarctic Minke Whale, Dark-shoulder Minke Whale	Migratory, Cetacean	Species or species habitat may occur within area
Balaenoptera edeni	Bryde's Whale	Migratory, Cetacean	Species or species habitat may occur within area
Orcinus orca	Killer Whale, Orca	Migratory, Cetacean	Species or species habitat may occur within area
Physeter macrocephalus	Sperm Whale	Migratory, Cetacean	Species or species habitat may occur within area
Sousa chinensis	Indo-Pacific Humpback Dolphin	Migratory, Cetacean	Species or species habitat may occur within area
Tursiops aduncus (Arafura/Timor Sea populations)	Spotted Bottlenose Dolphin (Arafura/Timor Sea populations)	Migratory, Cetacean	Species or species habitat likely to occur within area
Balaenoptera acutorostrata	Minke Whale	Cetacean	Species or species habitat may occur within area
Delphinus delphis	Common Dolphin	Cetacean	Species or species habitat may occur within area
Feresa attenuata	Pygmy Killer Whale	Cetacean	Species or species habitat may occur within area
Globicephala macrorhynchus	Short-finned Pilot Whale	Cetacean	Species or species habitat may occur within area
Grampus griseus	Risso's Dolphin, Grampus	Cetacean	Species or species habitat may occur within area
Kogia breviceps	Pygmy Sperm Whale	Cetacean	Species or species habitat may occur within area
Kogia simus	Dwarf Sperm Whale	Cetacean	Species or species habitat may occur within area
Lagenodelphis hosei	Fraser's Dolphin, Sarawak Dolphin	Cetacean	Species or species habitat may occur within area
Mesoplodon densirostris	Blainville's Beaked Whale, Dense-beaked Whale	Cetacean	Species or species habitat may occur within area
Peponocephala electra	Melon-headed Whale	Cetacean	Species or species habitat may occur within area
Pseudorca crassidens	False Killer Whale	Cetacean	Species or species habitat may occur within area
Stenella attenuata	Spotted Dolphin, Pantropical Spotted Dolphin	Cetacean	Species or species habitat may occur within area
Stenella coeruleoalba	Striped Dolphin, Euphrosyne Dolphin	Cetacean	Species or species habitat may occur within area
Stenella longirostris	Long-snouted Spinner Dolphin	Cetacean	Species or species habitat may occur within area
Steno bredanensis	Rough-toothed Dolphin	Cetacean	Species or species habitat may occur within area
Tursiops aduncus	Spotted Bottlenose Dolphin	Cetecean	Species or species habitat likely to occur within area
Tursiops truncates s. str.	Bottlenose Dolphin	Cetacean	Species or species habitat may occur within area
Ziphius cavirostris	Cuvier's Beaked Whale, Goose-beaked Whale	Cetacean	Species or species habitat may occur within area
Dugong dugon	Dugong	Migratory, Listed Marine Species	Species or species habitat likely to occur within area

Sea and Shore Bird Species of Conservation Significance (EPBC Act)

E

Scientific Name	Common Name	Status	Type of Presence
Macronectes giganteus	Southern Giant-Petrel	Endangered, Migratory, Listed Marine Species	Species or species habitat may occur within area
Puffinus pacificus	Wedge-tailed Shearwater	Migratory, Listed Marine Species	Breeding known to occur within area. Listed, overfly area
Sterna anaethetus	Bridled Tern	Migratory, Listed Marine Species	Breeding known to occur within area
Sterna bergii	Crested Tern	Listed Marine Species	Breeding known to occur within area
Sterna caspia	Caspian Tern	Migratory, Listed Marine Species	Breeding known to occur within area
Sterna dougallii	Roseate Tern	Listed Marine Species	Breeding known to occur within area
Apus pacificus	Fork-tailed Swift	Listed Marine Species	Species or species habitat may occur within area
Ardea alba	Great Egret, White Egret	Listed Marine Species	Species or species habitat may occur within area
Ardea ibis	Cattle Egret	Listed Marine Species	Species or species habitat may occur within area
Charadrius veredus	Oriental Plover, Oriental Dotterel	Migratory, Listed Marine Species	Species or species habitat may occur within area
Glareola maldivarum	Oriental Pratincole	Migratory, Listed Marine Species	Species or species habitat may occur within area
Numenius minutus	Little Curlew, Little Whimbrel	Migratory, Listed Marine Species	Species or species habitat may occur within area
Numenius phaeopus	Whimbrel	Migratory, Listed Marine Species	Species or species habitat likely to occur within area
Tringa nebularia	Common Greenshank	Migratory, Listed Marine Species	Species or species habitat likely to occur within area
Arenaria interpres	Ruddy Turnstone	Migratory, Listed Marine Species	Species or species habitat likely to occur within area
Haliaeetus leucogaster	White-bellied Sea-Eagle	Migratory, Listed Marine Species	Species or species habitat likely to occur within area
Hirundo rustica	Barn Swallow	Migratory, Listed Marine Species	Species or species habitat may occur within area
Merops ornatus	Rainbow Bee-eater	Listed Marine Species	Species or species habitat may occur within area

Pluto LNG Development Offshore Environment Plan Outline

F

1.1 Overview

Under the Petroleum Submerged Lands (Management of Environment) Regulations 1999 [P(SL) (MoE) Regulations], Environment Plans (EPs) are required for petroleum-related activities in Commonwealth waters.

Requirements of the PSL (MoE) Regulations also apply to Pluto LNG activities occuring in Western Australian waters, which are subject to the *Petroleum (Submerged Lands) Act* 1982 (WA) and Regulations, and *Petroleum Pipelines Act* 1969 (Section 8) and Regulations 1970. Shore crossing activities are subject to the *Petroleum Act* 1967 (WA) and Schedule of Onshore Petroleum Exploration and Production Requirements 1991.

Environment Plans have a management focus and describe proposed prevention, control and mitigation measures and performance objectives and standards to be followed in managing environmental risks and impacts to the required acceptable level. The preparation of EPs is partly prescriptive in that the scope and content are guided through government EP guidelines. The Plans must be approved by Government before work can commence.

A high level outline of the purpose and scope of the Environment Plan that will be prepared to manage offshore petroleum-related activities of the Pluto LNG Development is provided in **Section 1.2**.

The offshore activities will proceed through several stages. The intention, subject to government approval, is to prepare the EP as a modular plan. This plan will address management of different activities at different stages of the offshore work such as drilling of wells, installation of subsea equipment and flow lines, installation and construction of the offshore platform, hook up and commissioning, operations and decommissioning.

1.2 Purpose and Scope of the Environment Plan

An EP should 'outline specific safeguards and controls which would be employed to minimise or remedy environmental impacts'. In line with the guidelines, the EP will be structured to include the following key elements:

- *A Description of the Proposed Activity:* This section of the EP typically describes the technical detail pertaining to the proposed Development. Details on the location of the Development and a description of the development during all phases of the development are provided.
- *A Description of the Existing Environment:* A summary of the existing environment of the Development area will be provided which generally covers the following areas:
  - physical environment
  - biological environment
  - socio-economic environment
  - particular values and sensitivities.
- *Identification and Assessment of Environmental Effects and Risks:* The aspect, source, potential and predicted impact, management measures and residual risk are detailed covering the following activities:
  - drilling
  - installation and construction
  - operation
  - decommissioning of the facilities.
- *Environmental Objectives, Standards and Criteria:* Objectives and standards will be set to measure environmental effects and risks, to determine if an activity is meeting its environmental objectives and standards, and to assess the performance and implementation of the EP. The performance objectives and standards must be consistent with reducing environmental risks and effects to 'as low as reasonably practicable' (ALARP).
- *Environmental Management Techniques:* This section provides a description of the proposed safeguards and mitigation measures to be put in place for all phases of the proposed development. Safeguards and mitigation measures will be implemented to ensure that all significant environmental effects associated with the proposed development are minimised or avoided.

- *Implementation Strategy:* This section explains the strategy for implementing the EP. Details on the following are included:
  - Roles and Responsibilities: Key roles and responsibilities of personnel with respect to meeting environmental management and performance objectives during the various stages of the Pluto LNG Development.
  - Training and Education: The operational systems and procedures designed to ensure that each employee or contractor working on or in connection with the Development is aware of their responsibilities in relation to the environment and has the appropriate skills and training.
  - Monitoring, audit and reporting requirements: Arrangements for recording, monitoring and reporting information about the activity that will enable the relevant regulatory authority to determine whether the environmental performance objectives and standards in the EP have been met. A detailed audit and reporting schedule will be developed and implemented.
  - Environmental Monitoring: The implementation strategy will include information on monitoring programmes required to address management of impacts associated with the Development.
  - Emergency Events and Contingency Planning: The implementation strategy must establish and provide for maintenance of an up-to-date emergency response manual (including an oil spill contingency plan) with detailed response arrangements. Contingency plans must be approved before work can commence.
  - Consultations: Each EP will include information on consultations between the operator and relevant authorities, organisations or other interested parties in the course of developing the EP. It will also include details of ongoing consultation arrangements to be adopted during the operational phase with other marine users and interest groups.
- *Environmental Commitments:* In line with the Company Environmental Policy, the Pluto LNG Development will be undertaken in a manner that minimises impacts on the surrounding biophysical and social environments to acceptable levels. Accordingly, Woodside will adopt the management measures as outlined in the Draft PER.

1.3 Timing

Environmental Plans follow on as a natural extension from the environmental impact assessment process and the PER. With their strong focus on management, EPs are typically given effect once design has been progressed to a stage at which there is sufficient technical information available to describe proposed management measures to the required level of detail. Under the umbrella of a single plan, it is intended that component modular plans be prepared for the different phases of work and submitted for endorsement and approval by the relevant regulatory agencies.

Framework Environmental Management Plans

G

Terrestrial environmental aspects of the Development will be managed primarily through the development and implementation of Environmental Management Plans (EMPs). A consolidated overarching Environmental Management Programme will be developed to bring together all the individual EMPs, in accordance with recognised standards and applicable Commonwealth and Western Australian legislation. The consolidated Environmental Management Programme will be submitted to the relevant authorities for approval prior to the commencement of works.

Offshore Environment Plans (EPs) follow different requirements to onshore EMPs as the former are drawn up in accordance with the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999. An outline of the offshore EP requirements is included in **Appendix F**.

All EMPs will be drawn up in accordance with the management actions presented in **Table 13-1** of this Draft PER, and any ministerial conditions set as part of the approval process. The plans will describe the procedures proposed to prevent, monitor and manage possible environmental impacts.

Individual framework construction EMPs are presented in **Table G-1** to **Table G-17** and include the following:

- Sea Turtle Management Plan
- Marine Pest Management Plan
- Waste Water Management Plan
- Waste Management Plan
- Greenhouse Gas Management Plan
- Noise Management Plan
- Blasting Management Plan
- Erosion and Sediment Control Management Plan
- Groundwater and Surface Water Protection Plan
- Onshore Spill Response Plan
- Terrestrial Vegetation and Flora Management Plan
- Terrestrial Fauna Management Plan
- Weed Management Plan
- Dust Management Plan
- Cultural Heritage Management Plan
- Traffic Management Plan
- Rehabilitation Management Plan.

The framework EMPs for the construction phase will be developed further once detailed design information is available and the construction contractors are commissioned. The Greenhouse Gas Management Plan will be specifically developed for the operation phase and many of the plans, for example, the Waste Management and Cultural Heritage Management Plan, will be amended for operations. Framework plans are outlined in **Table G-1** to **Table G-17**.

Table G-1 Framework Sea Turtle Management Plan

Sea Turtle Management Plan Format	
Management Issues	• Vibration caused by terrestrial blasting may impact on development of turtle eggs at Holden Point beach. • Impacts from marine blasting may result in injury or mortality of foraging sea turtles in the vicinity • Impacts on sea turtles resulting from dredging and dredge spoil disposal. • Artificial lighting on nesting beaches can lead to reduced nesting attempts. Hatchlings will move towards these lights rather than the ocean.
Objectives	To minimise the impact of blasting activities, permanent structures, vessel movements and lighting on turtles including nesting and hatchling activity.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements.
Management Strategies	A Blasting Management Plan will be developed and implemented (refer to Table G 7). This will include the following measures in relation to impacts on sea turtles from terrestrial blasting: • Smaller, more frequent blasts will be planned using sequential explosive charges to minimise cumulative impacts of the explosions. • Blasting will only be undertaken during daylight hours. The Blasting Management Plan will also include the following measures in relation to impacts on sea turtles from marine blasting: • Marine fauna activities will be taken into consideration when blasting, drilling and/or dredging, especially during sensitive periods for fauna. • Procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence. A Dredging and Dredge Spoil Disposal Management Plan will be developed and implemented (refer to Appendix I). This will include the following measures in relation to sea turtles: • Prior to commencement of dredging activities, the dredging contractor and crew will receive induction that describes the location of sensitive sea turtle habitat in relation to proposed dredging activities. • The use of sea turtle deflection devices will be considered for use on trailer suction hopper dredges. These devices are not considered feasible for application to cutter suction dredges. An alternative to turtle deflectors which will also be considered are jetting systems. These systems force water and marine fauna (in particular sea turtles) away from the drag head, thereby avoiding any direct contact. Upon commencement of dredging, the jetting system will be switched on, prior to engaging the dredge pumps. When the dredging operation stops, the dredging pumps will be switched off prior to switching off the jetting system. • Prior to commencement of sea disposal activities, the dredging contractor will check for the presence of marine mammals and sea turtles within 300 m radius of the dredge vessel. • Disposal activities may only commence if no marine mammals or sea turtles have been observed within 300 m of the dredge vessel for ten minutes immediately preceding commencement of disposal operations. • Should any marine mammals or sea turtles be observed within 300 m of the vessel prior to and during disposal activities, disposal activities must stop and may not recommence until i) the animal/s are seen to move >300 m from the vessel ii) the animals have not been seen for >20 minutes duration or iii) the vessel moves to a location >300 m from the observed animals. • The dredging contractor will document any incidents that occur during disposal operations that result in injury or mortality of marine mammals or sea turtles. Details of the incident including time and date of incident, cause of injury/ mortality and the species (if known) will be recorded and reported to the Department of Environment and Conservation and the Department of the Environment and Heritage. • Sightings of sea turtles will be maintained in the vessels daily log book. Measures to reduce light emissions onto the beach to the west of Site A and onto the water from the standalone jetty will be implemented, as far as reasonably practicable. These measures may include: • Minimising lighting to ALARP in nearshore areas while maintaining safe construction and operating conditions. • Minimising light spill, particularly where white lights such as fluorescent lights are used.
Monitoring	The beach at Holden Point, Site A, will be monitored during the 2006 sea turtle nesting season (approximately December 2006 until April 2007) to assess the level of sea turtle nesting activity. Additional mitigation strategies will be developed, in consultation with the DEH and DEC, and included in the Sea Turtle Management Plan if monitoring results show there is significant turtle activity at the beach at Holden Point . Monitoring of the beach at Holden Point during construction in the turtle-nesting season for nests and hatchlings.
Reporting	• Reports will be compiled on the number of turtles that nest on the beach west of Site A.

Table G-2 Framework Marine Pest Management Plan

Marine Pest Management Plan Format	
Management Issues	The potential for the introduction of marine pest species.
Objectives	To minimise introduction of pest species into marine waters.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements.
Management Strategies	Application of the *Quarantine Act 1908* and Regulations 2000 (Cwth) and the AQIS ballast water management requirements for international shipping (July 2001) are a compulsory requirement for all vessels entering or leaving Australian waters. Where the potential risk is considered to be high, one or more of the following options for management of ballast water will be implemented: • no discharge of 'high risk' ballast tanks in Australian waters • tank-to-tank transfers • full ballast water exchange at sea (that is, beyond 12 nm from the coastline). Construction/installation vessels, including dredges, considered high risk with an overseas last port of call will be inspected prior to arriving on site. Inspections will include a focus on residual sediment on dredges and flotsam in the well around the cutter boom and head of cutter section dredges or ballast tanks. Undertake further investigation of marine pests during the operational stages of the Development.
Monitoring	Monitoring of the Marine Pest Management Plan will be undertaken against key performance indicators.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-3 Framework Waste Water Management Plan

Waste Water Management Plan Format	
Management Issues	The discharge of waste water may result in marine physical and ecological effects including reduced water quality and toxicity effects to marine biota.
Objectives	To comply with applicable legislation and guidelines. To minimise the potential for adverse impacts on water quality.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements
Management Strategies	• The residual total hydrocarbon in water concentration of waste water discharge will be less than 5 mg/l as an annual average for water discharged to Mermaid Sound. • Other measures employed to reduce the potential for environmental impact associated with waste water disposal are process design, procedures for chemical selection, dosing rates and operational maintenance and control of production equipment. • Woodside will put in place reduction targets and mitigation measures should the results of monitoring and/or investigations indicate a potential or actual unacceptable impact. • Pluto treated waste water composition will be determined and Whole Effluent Toxicity (WET) testing will be undertaken as soon as first water becomes available and periodically thereafter. Routine monitoring to ensure discharged waste water meets specified criteria. • Construction amenities will be regularly inspected and maintained, and effluent will be disposed of offsite at an appropriate facility. • During operation, approved sewage systems will be provided at Site B. • An appropriate monitoring and maintenance schedule for the sewage treatment system at Site B will be developed and implemented. • The oil-in-water meter will be regularly tested and calibrated as per acceptable standards to ensure its accuracy. • The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily. • A contingency plan will be developed to manage waste water in cases where unexpected volumes and/or quality of waste water are produced.
Monitoring	Monitoring of waste water will occur at source prior to commingling and at the discharge point. Waste water will be monitored in accordance with regulatory requirements. A comprehensive monitoring programme will be put in place to confirm the prediction of no significant impact to nearshore communities and to ensure contaminants are not bio-accumulated by marine organisms. This will include agreed 'trigger values' for initiation of further studies and remedial actions as necessary. Monitoring will confirm that a high level of ecological protection is being achieved at the edge of the agreed mixing zone. The concentration of total hydrocarbon in waste water discharged to Mermaid Sound will be measured daily. Routine monitoring to ensure treated waste water meets the Environmental Quality Management Framework (EQMF) social use values at end of pipe or within a distance, from point of discharge, agreed with the relevant authorities.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-4 Framework Waste Management Plan

Waste Management Plan Format	
Management Issues	Waste will comprise the following main streams: • Solid waste including earth works (construction phase only), domestic and green waste. • Liquid waste, including sanitary wastewater. • Hazardous waste, for example, insoluble salts, used oils and greases. Waste, if inappropriately managed, has the potential to contaminate groundwater and surface water and pose a risk to human health.
Objectives	To minimise environmental impacts associated with waste generation. Maximise waste reduction, recycling, reuse and recovery. Compliance with the *Environmental Protection Act 1986* (WA) and *Health Act 1911* (WA) (Part IV). To minimise impacts on existing waste facilities.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements.
Management Strategies	• Implementation of waste hierarchy: reduce, reuse, recycle and recover waste. • Inductions will provide details on waste management requirements for all waste streams. • Recycling bins will be located in strategic locations around site to facilitate segregation of waste, diverting recyclable solid waste streams from landfill. • All domestic waste will be stored in clearly marked skips and waste containers will be provided through out construction and operational sites. • Green waste will be segregated from other waste streams. The material will be mulched and reused on site if practicable. • Excavated soil will be either stored within the site boundary to enable reuse, reused locally where possible or disposed of at a 'clean fill' area at a licensed landfill facility. • Waste reduction at source will be included in tenders for supply and construction contractors. • Contractors will be required to place a high emphasis on housekeeping and all work areas will be required to be maintained in a neat and orderly manner. • All hazardous waste materials will be documented and tracked, segregated from other waste streams and stored in suitable containers. • All hazardous materials will be handled and stored in accordance with the corresponding MSDS and Australian Standards. • Hazardous materials storage facilities and handling equipment will be designed and constructed to prevent and contain spills. • Recyclable hazardous wastes will be segregated from other waste materials while non-recyclable hazardous wastes will be disposed of at an approved facility. • Appropriate controls on the AOCWS to enable isolation of spill events to prevent contamination of large volumes of liquid, and facilitating extraction of specific contaminated liquids.
Monitoring	Undertake visual inspections for litter/general waste (and clean up if required). Inspect waste storage and disposal facilities to ensure they are functioning effectively.
Reporting	Waste inventory catalogue held on file documenting disposal volumes and types and disposal locations. Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-5 Framework Greenhouse Gas Management Plan

Greenhouse Gas Management Plan Format	
Management Issues	Release of greenhouse gases from the Development may contribute to the greenhouse effect. Minimisation of greenhouse gas release will minimise loss of gas and improve plant efficiency.
Objectives	Reduce venting, flaring and combustion of hydrocarbons to as low as reasonably practicable.
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements
Management Strategies	Ensure greenhouse gas and energy efficiency of design by: • Inclusion of greenhouse gas emissions in all key design decisions and technology selections where relevant. • Energy efficiency review of the design • Maximising facility reliability, thereby reducing the likelihood that gas will require flaring due to process upset. Ensure efficient operation of the Pluto LNG Development by: • Minimising venting and flaring of hydrocarbons and fuel gas consumption by using procedural solutions to reduce venting, flaring and combustion of hydrocarbons to as low as reasonably practicable. • Minimising releases by ensuring equipment is correctly maintained.
Monitoring	Monitor and report emissions and periodically assess opportunities to further reduce greenhouse gas emissions over time. Information obtained will be used to enable reporting of emissions, performance reviews and setting reduction targets in line with Woodside's corporate initiatives.
Reporting	Greenhouse gas quantities emitted will be reported to Woodside for inclusion in the Woodside's Greenhouse Challenge reporting procedures and in Woodside's public Health, Safety, Environment and Community Report.

Table G-6 Framework Noise Management Plan

Noise Management Plan Format	
Management Issues	Noise during construction will be highly variable. Due to the distance from residential areas, noise impacts on the local community are not expected to occur. Noise from the construction phase of the Development will be generated by: • general civil or earthworks operations • blasting • construction works on site • traffic of vehicles, excavators and other machinery. The following noise sources will dominate received noise levels during the operation phase: • compressor suction • discharge and recycle piping • air coolers.
Objectives	To minimise the impacts of noise on the amenity of the surrounding areas during the construction and operation phases of the Development to ALARP. Construction activities undertaken in accordance with AS 2436-1981 'Guide to Noise Control on Construction, Maintenance and Demolition sites'. Construction activities undertaken in accordance with Western Australia's Environmental Protection (Noise) Regulations 1997.
Performance Indicators	Noise levels close to 45 dBA at the Hearson Cove beach shelter. No noise complaints lodged.
Management Strategies	*Construction* For construction work outside the hours of 7am to 7pm, and for Sundays and public holidays, Woodside will: • Advise all nearby occupants or other sensitive receptors who are likely to receive noise levels which fail to comply with the standard under Regulation 7, of the work to be done at least 24 hours before it commences. • Submit a Noise Management Plan to the EPA at least seven days before the commencement of construction, with the plan requiring approval by the CEO. A Traffic Management Plan (**Table G-16**) will be developed and implemented to control vehicle operations and potential impacts on human receptors. *Operation* • Measures to be considered include low noise air-cooling fans and acoustic lagging on compressor suction, discharge and recycle piping. • Detail design will ensure noise levels from flaring are below the Woodside absolute standard for noise emissions of 115 dB(A) at ground level. • Minimising flaring of hydrocarbons by using procedural solutions to reduce flaring to as low as reasonably practicable.
Monitoring	Maintain and monitor the noise control strategies to determine effectiveness.
Reporting	Develop reporting procedures consistent with regulatory, local and Development requirements.

Table G-7 Framework Blasting Management Plan

Blasting Management Plan Format	
Management Issues	Blasting on the site has the potential to result in: • increased dust emissions • unacceptable noise levels • restriction of public access to surrounding areas • vibration • behavioural changes, physical injuries or mortality to terrestrial and marine fauna.
Objectives	To ensure the safety of construction personnel and members of the general public during blasting operations. To minimise the noise and vibration impacts associated with blasting. To minimise impacts to terrestrial and marine fauna. To comply with Western Australia's Environmental Protection (Noise) Regulations 1997. To comply with AS 2187.2-1983. Comply with *Explosives and Dangerous Goods Act 1961* (WA), the Explosives and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations 1992 and Explosives and Dangerous Goods (Explosives) Regulations 1963.
Performance Indicators	No risk of exposure to public during blasting activities, including no public access to beach west of Site A. No complaints in relation to noise, dust and vibration. No terrestrial fauna, seabird, sea turtle or marine mammal injury or mortality.
Management Strategies	Measures to mitigate impacts on the terrestrial environment from blasting activities which will be determined by the blasting contractor may include: • Explosives will be used in a manner that will minimise damage or defacement of landscape features and other surrounding objects including the following practices: – increasing the depth of material cover – the use of blankets to minimise upward release of energy and fly rock – optimising charge sizes and spacings to avoid unnecessary energy releases. • Blasting will be scheduled for daylight hours to avoid impacts during peak activity times (dusk, night, dawn) for nocturnal fauna. • Use of sirens and signage to inform construction personnel and members of public that blasting will take place. • Public access to the beach at Site A will be restricted during blasting activities. Warning signs will be placed on the beach, and an observer will monitor the beach from a safe location (either on the beach or a nearby boat) to prevent boats landing or to stop blasting until the beach is cleared. • Blasting will only be used where absolutely necessary and will be carried out in a manner to reduce noise disturbance to a minimum. • Use of explosives will be restricted to authorized personnel who have been trained in their use. • Local residents near the trunkline corridor will be notified of construction activities in advance. Measures specific to mitigate impacts on the marine environment from blasting may include: • Marine fauna activities will be taken into consideration when blasting, drilling and/or dredging, especially during sensitive periods for fauna. • Procedures will be developed to ensure a marine mammal and sea turtle watch is maintained in the blast area before blasting activities commence. • To minimise injury to seabird species dead fish on the surface of the water after a blast will be collected to prevent bird injuries or mortality from successive blasts. A Noise Management Plan (**Table G-6**) will be developed and implemented.
Monitoring	Monitoring of the Blasting Management Plan will be undertaken against key performance indicators.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-8 Framework Erosion and Sediment Control Management Plan

Erosion and Sediment Control Management Plan Format	
Management Issues	Erosion may occur as a result of: • vegetation clearing • earthmoving activities • wind or water action on cleared areas and/or stockpiles • alteration of existing drainage patterns Sedimentation could occur in drainage lines as a result of: • vegetation clearing • earthmoving activities • blasting • run-off during wet periods.
Objectives	To ensure that the effects of erosion and sedimentation on the environment and biological communities are minimised. Minimise soil disturbance, degradation and erosion. Minimise turbidity impacts on marine and surface waters. Compliance with *Soil and Land Conservation Act 1945* (WA).
Performance Indicators	No accelerated erosion and run-off during and post construction works. No visible increase in turbidity of marine or surface waters.
Management Strategies	• The total area to be disturbed will be restricted to the minimum area required for the Development. • Runoff control measures will be implemented. • Sediment/silt fences will be installed to trap sediment runoff downstream of construction areas. • Stormwater drainage will be installed at all major storm water outlets within Site B and A. • Movement of vehicles will be restricted to designated roads/tracks, and will adhere to onsite speed limits. • Where installation of sediment traps is not possible, provide temporary sediment control, such as silt fences or interceptor ditches. • Erosion and sediment control structures will be routinely inspected and maintained to ensure they remain effective, including the removal of accumulated silt as required. • Minimise steepness and length of slope of created landforms. • Areas susceptible to slope instability will be stabilised. • Provide adequate drainage system for permanent hard standing. • A Rehabilitation Management Plan (**Table G-17**) will be developed and implemented.
Monitoring	Visual monitoring of all sites and access routes to be undertaken. Monitoring of the effectiveness of sedimentation and dust control measures undertaken regularly during and post construction works.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-9 Framework Groundwater and Surface Water Protection Plan

Groundwater and Surface Water Management Plan Format	
Management Issues	Impacts from a reduction in groundwater and surface water quality and quantity may occur as a result of: • vegetation and soil disturbance during construction • interruption of drainage lines • groundwater interception • leakage and spillage from fuel and chemical storage, handling and distribution systems during construction and operation • sewage and grey water disposal from onsite facilities • disposal of hydrotest water during operations • contaminated stormwater runoff • disturbance of acid sulfate soils (if they exist) • pressure on potable water supplies.
Objectives	To maintain the existing quality of water resources. To minimise the potential for ground and surface water contamination. To minimise pressure on existing water resources. Compliance with relevant legislation, including meeting ANZECC guideline criteria.
Performance Indicators	No measurable changes to downstream water quality during construction and operation.
Management Strategies	• Hierarchal drainage water management system designed to segregate clean water and treat potentially contaminated water. • Strict storage procedures will be maintained for environmentally hazardous materials. • Strict procedures will be implemented to prevent the leaks or spills of hydrocarbons. • Measures will be employed to reduce the risk of flooding such as bunding or raising of site elevation. • Consideration will be given to treatment of surface water runoff through sediment or evaporation ponds for nutrient removal via bioremediation of waters. • Where considered necessary, re-vegetation of bare soil embankments with suitable native species will be undertaken to reduce erosion and exposure of bare soils. • Should detailed geotechnical investigations and further desktop assessment indicate that Acid Sulphate Soils (ASS) are likely to be present within the Development area, a site investigation will be conducted to consider the specific location or locations of disturbance; the nature of disturbance; volume of material to be disturbed and maximum depth of disturbance. • Unnecessary soil compaction and vegetation removal will be avoided to reduce surface flows from site. • Should further desktop ASS assessment and any follow up investigations indicate that ASS are present, then a detailed ASS Management Plan will be developed, which will include measures to eliminate the potential impacts of ASS. • Chemicals used as inputs into the hydrotest water will be chosen to ensure that the most appropriate environmental and technical solutions are achieved for the Development. • A Pipeline Flooding and Hydrotesting Procedure and a Pipeline Pre-commissioning Procedure will be developed. • Ensuring use of water for hydrotesting, dust suppression, potable supplies is correctly permitted and approved. An Erosion and Sediment Control Plan will be developed and implemented as per **Table G-8**. An Onshore Spill Response Plan (**Table G-10**) will be developed and implemented. A Waste Water Management Plan (**Table G-3**) will be developed and implemented, and will include the separation of contaminated stormwater and the appropriate disposal of sewage and grey water.
Monitoring	A water monitoring programme will be developed and implemented at Site B and Site A. Determine depths to groundwater from geotechnical investigations and design a monitoring program accordingly.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-10 Framework Onshore Spill Response Plan

Spill Protection and Response Plan Format	
Management Issues	Accidental spills have the potential to contaminate groundwater and surface water and pose a risk to human health.
Objectives	To ensure effective management measures are deployed in the event of a spill. Minimise impacts on soils, surface and groundwater. Compliance with the *Environmental Protection Act 1986* (WA), Environmental Protection (Unauthorised Discharges) Regulations 2004 and *Health Act 1911* (WA) (Part IV and IV).
Performance Indicators	Performance indicators will be developed consistent with relevant regulatory, local and Development requirements
Management Strategies	• Site inductions prior to construction activities will include correct materials handling procedures, spill management and spill response procedures. • Prior to the commencement of construction activities, appropriate and specific strategies and actions will be identified for spill events. Responsibilities for action, notification and reporting will also be identified. • Appropriate equipment, such as spill clean up kits and Material Safety Data Sheets, will be available onsite in easily accessible locations. • Spills will be cleaned up immediately to avoid contamination. • Fuel and chemical storage and handling (including refuelling) areas will be regularly inspected. • Vehicles and equipment will be appropriately maintained. • Notification of appropriate authorities and compliance with reporting requirements in the event of a spill.
Monitoring	Monitoring of the effectiveness of spill contingency measures undertaken regularly during and post construction works.

Table G-11 Framework Terrestrial Vegetation and Flora Management Plan

Vegetation and Flora Management Plan Format	
Management Issues	Construction activities have the potential to negatively impact on terrestrial vegetation and flora by: • permanently removing or temporarily disturbing native vegetation • disturbing significant vegetation communities and habitats either directly or indirectly through off-site impacts • removing or disturbing Priority 3 flora species • introducing and\or spreading weed species (refer to **Table G-13**).
Objectives	To minimise the amount of vegetation that is permanently cleared. To minimise the effects of construction on Priority flora species. To prevent disturbance of vegetation and flora adjacent to work areas.
Performance Indicators	No disturbance to vegetation outside of the approved construction area.
Management Strategies	• Pluto LNG Development design will avoid significant vegetation communities and habitats wherever possible. • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared • The boundaries of the working area will be verified by an environmental advisor prior to the works to ensure that significant vegetation communities and habitat are avoided as intended in the design. • Vegetation communities of conservation significance in proximity to working areas will be clearly marked and access to these areas will be prohibited. • Access for vehicles and machinery will be along designated access tracks and parking areas. • The DEC will be consulted regarding the development of suitable management procedures for Priority flora. • All personnel will be required to undertake an induction which will include details on the importance of vegetation and flora protection. Dust control measures will be incorporated into the Dust Management Plan (refer to **Table G-14**). Fire control measures will be incorporated into the Vegetation and Flora Management Plan. A Rehabilitation Management Plan will be developed and implemented as given in **Table G-17**. A Weed Management Plan will be developed and implemented as per **Table G-13**.
Monitoring	Visual and photo monitoring of vegetation disturbance adjacent to the working areas and close to high conservation areas (including Priority flora and drainage lines) will be undertaken during clearing and construction.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-12 Framework Terrestrial Fauna Management Plan

Fauna Management Plan Format	
Management Issues	Construction activities have the potential to impact on terrestrial fauna by: • increasing activity levels, vehicle movement, noise and dust • habitat removal and fragmentation • capture in open excavations • introduction and spread of introduced species and diseases.
Objectives	To minimise impacts on terrestrial fauna and habitats. To minimise impacts on fauna species of conservation significance. To minimise death of fauna as a result of capture in open excavations or vehicle strike. To prevent the spread of introduced species.
Performance Indicators	No disturbance of habitats outside of the approved working areas.
Management Strategies	• Inductions will provide details on terrestrial fauna management requirements. • The working area will be clearly marked on all construction drawings and physically flagged on the ground to ensure only the minimum area required is cleared. • The boundaries of the working area will be verified by an environmental advisor prior to the works to ensure that sensitive fauna habitats are avoided as intended in the design. • Vegetation clearance during trunkline construction is undertaken in a manner designed to allow fauna to move away from the site. • Traffic is kept to designated tracks and drivers will abide by the allocated speed limit to minimise fauna fatality or injury by moving vehicles (**Table G-16**). • All domestic animals will be prohibited from the Development area. • Measures will be in place to protect the Pilbara olive python, including relocation of Pilbara olive pythons found during earthworks by trained handlers. A Sea Turtle Management Plan (**Table G-1**) will be developed and implemented.
Monitoring	Inspections of open excavations to remove trapped fauna. Monitoring of habitat disturbance in and adjacent to the working areas will be undertaken for the duration of the works. Sightings of threatened species will be recorded. Inspections for introduced animals will be undertaken, and observations will be reported to the Site Supervisor. Follow-up actions will be recorded.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed

Table G-13 Framework Weed Management Plan

Weed Management Plan Format	
Management Issues	The use of earthmoving equipment, vehicles, and construction materials from elsewhere in the region and Australia has the potential to introduce weeds and exotic species that currently do not occur in the area. Vegetation clearing and soil disturbance creates suitable conditions for the establishment and spread of weed species. Once weed species become established they compete with native vegetation and they may adversely affect native fauna.
Objectives	To prevent the introduction and spread of weed species.
Performance Indicators	No new weed species introduced into the Development area. No spread of existing weed species into new areas from the Development area.
Management Strategies	• Identify and assess controllability of existing weed infestations. • Establish and maintain plant, vehicles and equipment hygiene to prevent introduction and transfer of weeds. • Monitor weeds during site preparation works/construction and operations. • Implement weed control methods to manage any new weed infestations during construction and operations, where they can be effectively controlled. • Organic packaging material will be checked, removed and sent to an approved facility for disposal. • Construction workforce will be trained in weed identification and awareness. • Systems will be established for reporting of new weed infestations.
Monitoring	A weed monitoring and treatment programme will be implemented prior to the commencement of construction activities and will continue for the duration of the Development. The programme will identify appropriate treatment and control techniques for weed species encountered in the Development area. Regular inspections of vehicles, equipment, construction materials and fill will be undertaken to monitor the success of preventative measures. Carry out periodic weed inspections.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-14 Framework Dust Management Plan

Dust Management Plan Format	
Management Issues	During construction works dust will be generated as a result of: • vehicular movements on unsealed roads/tracks • clearing of vegetation • earthmoving activities • vehicle movements on unsealed tracks • drilling and blasting • operation of mobile crushing plant • machinery operating along the gas export trunkline construction corridor • wind action on cleared areas and/or stockpiles. Dust emissions may adversely affect vegetation and fauna, human health and safety, and public amenity. Erosion may increase dust generation and the impacts described above.
Objectives	To ensure that the effects of dust generation on the environment and communities are minimised.
Performance Indicators	No complaints lodged. No visible dust crossing site boundaries.
Management Strategies	• The area disturbed will be the minimum required for construction. • Exposed surfaces such as stockpiles and cleared areas, and the duration that these areas are exposed, will be minimised. • Dust suppression techniques and/or watering of unsealed roads, access routes, exposed ground surfaces and stockpiles will be implemented. • General housekeeping practices will be undertaken to ensure there is no accumulation of waste materials, within the construction area, that may generate dust. • Rehabilitation of vegetation will be undertaken in temporarily disturbed areas to minimise dust generation. • During the site induction the workforce will be made aware of dust generation and control measures. • Ensure that vehicles, machinery and loads are properly maintained and covered to minimise dust emissions. • The construction contractor will be made aware of the requirements to minimise ambient dust levels. A Rehabilitation Management Plan will be developed and implemented (**Table G-17**). A Traffic Management Plan (**Table G-16**) will be developed and implemented which will ensure stringent controls on vehicle speeds and restricting travel to designated roads/tracks during construction activities.
Monitoring	Visual monitoring of all sites and access routes and construction sites to be undertaken. Monitoring of the effectiveness of erosion control measures to be undertaken regularly during and post construction works.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-15 Framework Cultural Heritage Management Plan

Cultural Heritage Management Plan Format	
Management Issues	Loss or impairment to existing Aboriginal heritage assets through disturbance to Aboriginal heritage sites.
Objectives	Identify all Aboriginal heritage sites through archaeological and anthropological heritage surveys with relevant Traditional Owners. Use the results of the heritage surveys to design footprint that will avoid damage to cultural heritage sites as far as possible. Manage and minimise the disturbance of environments that are of cultural significance. Comply with the *Aboriginal Heritage Act 1972* (WA).
Performance Indicators	No disturbance/inadvertent intrusion to cultural heritage sites and objects outside the Development area. Provide effective permanent protection and management for preserved cultural heritage sites.
Management Strategies	A detailed Cultural Heritage Management Plan (CHMP) will be developed and implemented in consultation and collaboration with Indigenous groups and the State Government. • Disturbance to sites will be minimised as far as possible. Where disturbance to sites cannot be avoided, archaeological material will be relocated to designated conservation areas wherever practicable; site destruction is always a last resort. • Any proposed disturbance to cultural heritage sites will be subject to application under Section 18 of the Aboriginal Heritage Act. • Aboriginal sites near work areas will be managed to prevent avoidable impact. • A cultural heritage induction be included within the Pluto LNG Development site access inductions. • Initial site preparation works will be monitored by Aboriginal representatives. • Any archaeological discoveries during site preparation work will be reported to the regulatory authority in accordance with reporting and mitigation measures identified in the CHMP, state government policy and the expectations of the Indigenous groups. • Indigenous representatives will be involved in all stages of mitigative relocation. • Access to conservation areas by Indigenous groups will be maintained, subject to operational and occupational health, and safety constraints.
Monitoring	Monitoring of the CHMP implementation will be undertaken against key performance indicators identified in the CHMP. Monitoring of the activities and impact of the site preparation workforce on the social and cultural environment will be undertaken. Archaeologists and representatives from relevant Indigenous Groups to monitor ground disturbance associated with laying the trunkline.
Reporting	Archaeological and ethnographic heritage survey reports and site records prepared will be submitted to DIA and Indigenous groups. Any archaeological discoveries during earthworks will be reported to the regulatory authority in accordance with reporting and mitigation measures identified in the CHMP, State Government policy and the expectations of the Indigenous groups. Initial ground disturbance will be monitored by representatives from the Indigenous groups of the area and archaeologists.

Table G-16 Framework Traffic Management Plan

Traffic Management Plan Format	
Management Issues	Road closures due to transport of construction components and trunkline construction. Delays to emergency vehicles during construction phase. Increased traffic volumes on road network during construction and operation phases. Structural damage to municipal roads from heavy vehicle movements. Excess levels of dust produced from heavy vehicle movement. Threat to terrestrial fauna from increased vehicle movements. Impacts from increased noise levels from vehicle movements.
Objectives	To ensure site traffic is managed in such a way so as not to adversely impact on community, road users, road infrastructure and sensitive habitats. To minimise dust generation through traffic movements.
Performance Indicators	No complaints lodged. Zero-incidents safety record.
Management Strategies	• Emergency access will be provided for at all times. • Identify existing traffic volumes on the public road network. • Determine the traffic flow as a result of construction activities. • Identify construction periods which will result in lessened impact on existing public road network traffic. • Monitor the impact of heavy vehicles on the public road network. • Identify the location of truck lay-up areas to be used outside of their usage periods. • Advise on the access restrictions imposed on each vehicle type. • Provide nominated personnel responsible for each traffic management activity. • Assessment of intersections suitable for the movement of pre-assembled units and provision of advice on changes to accommodate these. • The coordination of all activities on the road network with Main Roads WA and the Shire of Roebourne. • Transport slow moving heavy machinery and vehicles to site outside of road network peak periods. • Internal site traffic will be restricted to designated routes to maximise the safety potential and reduce the likely impact on the natural environment. • A speed limit of 40 km/hr on access roads, 10 km/hr within the site, and 5 km/hr will be implemented when passing personnel. A Dust Management Plan (**Table G-14**) will be developed and implemented. A Terrestrial Fauna Management Plan (**Table G-12**) will be developed and implemented. A Noise Management Plan (**Table G-6**) will be developed and implemented.
Monitoring	Monitor the impact of heavy vehicles on the road network.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Table G-17 Framework Rehabilitation Management Plan

Traffic Management Plan Format	
Management Issues	Successful regeneration of mangroves. Effective rapid rehabilitation strategies are required to stabilise and restore the land following construction activities so that erosion and establishment of weed species are prevented.
Objectives	To maximise rehabilitation success, by: • Minimising the effects of vegetation clearance. • Ensuring that the area is suitably rehabilitated with reference to the control of erosion and sedimentation.
Performance Indicators	Rehabilitation work commenced immediately following construction activities. Soils stabilised prior to the wet season.
Management Strategies	• A site specific rehabilitation strategy will be developed prior to the commencement of construction activities. The strategy will include a rehabilitation timetable and rehabilitation methods proposed for each aspect of the Development. The following are examples of actions that will be included in the strategy: – Rehabilitation and stabilisation will be undertaken following completion of the construction activities. – Vegetative matter and topsoil cleared from the working areas will be stockpiled for use in rehabilitation.
Monitoring	Rehabilitation works will be monitored following completion of construction activities.
Reporting	Reporting procedures consistent with regulatory, local and Development requirements will be developed.

Scleractinian Corals of the Dampier Archipelago

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	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Family Acroporidae				
Acropora abrolhosensis			x	
Acropora aculeus			x	
Acropora acuminata			x	
Acropora anthocercis			x	
Acropora aspera			x	
Acropora austera		x	x	
Acropora cerealis	x		x	
Acropora clathrata		x	x	
Acropora cytherea	x	x	x	
Acropora danai			x	
Acropora dendrum		x	x	
Acropora digitifera	x		x	
Acropora divaricata	x		x	
Acropora donei	x			
Acropora florida		x	x	
Acropora formosa	x	x	x	
Acropora gemmifera		x	x	
Acropora glauca		x	x	
Acropora grandis			x	
Acropora horrida			x	
Acropora humilis	x	x	x	
Acropora hyacinthus		x	x	
Acropora kosurini		x		
Acropora latistella		x	x	
Acropora listeri	x		x	
Acropora loripes			x	
Acropora lovelli			x	
Acropora lutkeni			x	
Acropora microclados	x			
Acropora microphthalma		x	x	
Acropora millepora		x	x	
Acropora nana			x	
Acropora nasuta	x		x	
Acropora nobilis	x	x	x	
Acropora polystoma			x	
Acropora pulchra			x	
Acropora robusta		x	x	
Acropora samoensis	x	x	x	
Acropora sarmentosa			x	
Acropora secale	x		x	
Acropora selago			x	
Acropora solitaryensis		x	x	
Acropora spicifera	x		x	

	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Acropora stoddarti			x	
Acropora subulata			x	
Acropora tenuis	x	x	x	
Acropora tortuosa			x	
Acropora valenciennesi			x	
Acropora valida	x		x	
Acropora vaughani			x	
Acropora verweyi	x	x	x	
Acropora yongei		x	x	
Recorded as *Astreopora explanata* Veron 1985 also known as *Astreopora expansa* Brüggemann 1877			x	
Astreopora gracilis	x		x	
Astreopora myriophthalma	x	x	x	
Montipora aequituberculata			x	
Montipora calcarea			x	
Montipora caliculata			x	
Montipora capricornis			x	
Montipora crassituberculata			x	
Montipora danae		x	x	
Montipora digitata			x	
Montipora efflorescens			x	
Montipora foliosa	x		x	
Montipora foveolata			x	
Montipora grisea			x	
Montipora hispida		x	x	
Montipora hoffmeisteri			x	
Montipora incrassata			x	
Montipora informis		x	x	
Montipora millepora			x	
Montipora mollis			x	
Montipora monasteriata			x	
Montipora peltiformis			x	
Montipora spongodes			x	
Montipora spumosa			x	
Montipora stellata			x	
Montipora tuberculosa			x	
Montipora turgescens		x	x	
Montipora turtlensis			x	
Montipora undata			x	
Montipora venosa			x	
Montipora verrucosa	x		x	
Family Agariciidae				
Gardinoseris planulata			x	
Pachyseris rugosa		x	x	
Pachyseris speciosa			x	
Pavona clavus			x	
Pavona decussata	x	x	x	
Pavona explanulata			x	
Recorded as *Pavona minuta* Wells 1954 also known as *Pavona duerdeni* Vaughan 1907			x	
Pavona varians			x	

	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Family Astrocoeniidae				
Stylocoeniella guentheri			x	
Family Caryophylliidae				
Caryophyllia rugosa				x
Caryophyllia transversalis				x
Deltocyathus magnificus				x
Heterocyathus aequicostatus				x
Heterocyathus alternatus				x
Heterocyathus hemisphaericus				x
Paracyathus rotundatus				x
Family dendrophylliidae				
Duncanopsammia axifuga		x	x	
Heteropsammia cochlea			x	
Rhizopsammia verrilli				x
Tubastraea coccinea				x
Tubastraea diaphana		x		x
Tubastraea micranthus				x
Tubastrea spp.	x			
Turbinaria bifrons	x	x	x	
Turbinaria conspicua		x	x	
Turbinaria frondens	x	x	x	
Turbinaria mesenterina	x	x	x	
Tubinaria patula	x		x	
Turbinaria peltata		x	x	
Turbinaria reniformis	x	x	x	
Turbinaria stellulata	x		x	
Family Euphyllidae				
Catalaphyllia jardinei		x	x	
Euphyllia ancora	x	x	x	
Euphyllia cristata			x	
Euphyllia divisa			x	
Euphyllia glabrescens			x	
Physogyra lichtensteini			x	
Plerogyra sinuosa			x	
Family Faviidae				
Barabattoia amicorum			x	
Caulastrea tumida	x	x	x	
Cyphastrea chalcidicum	x	x		
Cyphastrea microphthalma	x	x	x	
Cyphastrea serailia	x	x	x	
Diploastrea heliopora		x	x	
Echinopora gemmacea		x		
Echinopora hirsutissima			x	
Echinopora horrida			x	
Echinopora lamellosa		x	x	
Favia favus	x	x	x	
Favia lizardensis			x	
Favia maritima	x			
Favia marshae		x		
Favia matthaii	x	x	x	
Favia maxima	x	x	x	

	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Favia pallida	x	x	x	
Favia rotumana		x	x	
Favia rotundata			x	
Favia speciosa	x	x	x	
Favia stelligera	x	x	x	
Favia veroni		x	x	
Favites abdita	x	x	x	
Favites chinensis		x	x	
Favites complanata	x	x	x	
Favites flexuosa	x	x	x	
Favites halicora	x	x	x	
Favites pentagona	x	x	x	
Favites russelli	x	x	x	
Goniastrea aspera	x	x	x	
Goniastrea australensis	x	x	x	
Goniastrea edwardsi		x	x	
Goniastrea favulus	x	x	x	
Goniastrea palauensis		x	x	
Goniastrea pectinata	x	x	x	
Goniastrea retiformis	x	x	x	
Leptastrea pruinosa	x	x	x	
Leptastrea purpurea	x		x	
Leptastrea transversa	x	x	x	
Leptoria phrygia	x	x	x	
Montastrea curta	x	x	x	
Montastrea magnistellata	x		x	
Montastrea valenciennesi		x	x	
Moseleya latistellata		x	x	
Oulophyllia bennettae			x	
Oulophyllia crispa			x	
Platygyra acuta		x		
Platygyra daedalea	x	x	x	
Platygyra lamellina		x	x	
Recorded as *Platygyra lamellosa* Unknown species, possibly *P. lamellina*	x			
Platygyra pini	x	x	x	
Platygyra ryukyuensis		x	x	
Platygyra sinensis	x	x	x	
Platygyra verweyi	x	x	x	
Plesiastrea versipora	x		x	
Family Flabellidae				
Flabellum hoffmeisteri				x
Flabellum lamellulosum				x
Flabellum magnificum				x
Flabellum politum				x
Placotrochus laevis				x
Truncatoflabellum aculeatum				x
Truncatoflabellum angiostomum				x
Truncatoflabellum macroeschara				x
Family Fungiacyathidae				
Fungiacyathus paliferus				x

	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Family Fungiidae				
Fungia concinna			x	
Recorded as *Fungia cyclolites* Lamarck 1816 Also known as *Cycloseris cycloites* Lamarck 1801		x	x	
Fungia echinata	x			
Fungia fungites	x	x	x	
Fungia repanda		x	x	
Fungia scutaria			x	
Fungia spp.	x			
Herpolitha limax		x	x	
Lithophyllon undulatum		x	x	
Recorded as *Lithophyllon edwardsi* Also known as *Lithophyllon lobata* Horst 1921	x			
Podabacia crustacea	x	x	x	
Polyphyllia talpina		x	x	
Family Meruliniidae				
Hydnophora exesa	x	x	x	
Hydnophora microconos	x	x	x	
Hydnophora pilosa	x	x	x	
Hydnophora rigida	x		x	
Merulina ampliata	x	x	x	
Merulina scabricula			x	
Scapophyllia cylindrica			x	
Family Mussidae				
Acanthastrea echinata	x	x	x	
Acanthastrea hillae	x		x	
Acanthastrea lordhowensis			x	
Australomussa rowleyensis			x	
Blastomussa merleti			x	
Lobophyllia corymbosa	x	x	x	
Lobophyllia hataii			x	
Lobophyllia hemprichii	x	x	x	
Symphyllia agaricia	x	x	x	
Symphyllia radians	x			
Symphyllia recta			x	
Symphyllia valenciennesii			x	
Family Oculinidae				
Galaxea astreata	x	x	x	
Galaxea fascicularis	x	x	x	
Family Pectinidae				
Echinophyllia aspera	x	x	x	
Echinophyllia orpheensis			x	
Mycedium elephantotus	x	x	x	
Oxypora lacera			x	
Pectinia lactuca		x	x	

	LEC (1991)	Blakeway and Radford (2004)	Griffith (2002)* Hermatypic	Griffith (2002) ** *Azooxanthellate*
Family Pocilloporidae				
Pocillopora damicornis		x	x	
Pocillopora eydouxi			x	
Pocillopora meandrina			x	
Pocillopora verrucosa			x	
Pocillopora woodjonesi			x	
Seriatopora caliendrum			x	
Stylophora pistillata		x	x	
Family Poritidae				
Alveopora fenestrata			x	
Goniopora columna			x	
Goniopora djiboutiensis		x	x	
Goniopora lobata			x	
Goniopora minor	x		x	
Goniopora palmensis			x	
Goniopora pandoraensis			x	
Goniopora pendulus	x	x	x	
Goniopora stokesi			x	
Goniopora stutchburyi	x	x	x	
Goniopora tenuidens		x	x	
Porites annae	x			
Porites aranetai			x	
Porites cylindrica		x	x	
Porites evermanni			x	
Porites heronensis			x	
Porites lichen			x	
Porites lobata	x	x	x	
Porites lutea	x	x	x	
Porites murrayensis	x		x	
Porites rus			x	
Porites solida	x	x	x	
Family Rhizangiidae				
Culicia sp.				x
Family Siderastreidae				
Coscinaraea columna	x	x	x	
Coscinaraea exesa Dana 1846 also spelt *C. exaesa* Dana 1846		x	x	
Pseudosiderastrea tayami	x	x	x	
Psammocora contigua		x	x	
Psammocora digitata		x	x	
Psammocora explanulata			x	
Psammocora haimeana	x		x	
Psammocora nierstraszi			x	
Psammocora profundacella	x	x	x	
Psammocora superficialis	x	x	x	
Family Trachyphylliidae				
Trachyphyllia geoffroyi		x	x	
Family Turbinoliidae				
Notocyathus venustus				x
Conocyathus gracilis				x
Conocyathus zelandiae				x

* Compiled from Hoeksema (1989), Simpson (1988), Veron (1993), Veron and Marsh (1988), Griffith (2002) and registration records from the Western Australian Museum. Only corals identified to species level are included.

** Compiled from Cairns (1998) and registration records from the Western Australian Museum

Framework Dredging and Spoil Disposal Management Plan

I

1. Purpose and Objectives of the Plan

1.1 Purpose

This Framework Dredging and Spoil Disposal Management Plan (DSDMP) has been prepared to support the Pluto LNG Development Draft Public Environmental Review/ Draft Public Environmental Report (PER). It specifically outlines the range of management and monitoring measures that will provide the basis for the development of a detailed DSDMP. The purpose of the framework DSDMP is to provide Woodside, stakeholders and relevant regulatory authorities with the level of assurance that environmental impacts predicted during the dredging programme are reduced to As Low As Reasonably Practicable (ALARP) and that dredging activities are conducted in a manner consistent with Woodside's Environment Policy.

The Framework DSDMP will be refined in consultation with Commonwealth and state regulatory agencies as further specific details of the dredging programme become available and when a dredging contractor is appointed.

1.2 Objectives

The objectives of the Framework DSDMP are to:

1) outline the basis of the dredging programme at the time of Draft PER submission to the Commonwealth Department of Environment and Heritage (DEH) and the Western Australian Environmental Protection Authority (EPA)
2) define the areas that are predicted to be impacted by turbidity plumes and sedimentation based on the results of a numerical modelling exercise
3) assess potential environment impacts of predicted disturbances associated with the proposed dredging activities
4) define measures for protecting the ecological, social and commercial values within the Dampier Archipelago from the effects of predicted disturbances associated with the proposed dredging activities, including prevention of losses of benthic primary producer habitat outside the expected areas of unavoidable loss identified in the Draft PER
5) present an outline of the management and monitoring measures, including a suite of water quality and coral monitoring programmes that will be implemented to limit potential environmental impacts.

1.3 Potential Environmental Issues

The potential environmental issues associated with the proposed dredging activities have been rigorously assessed as part of the environmental impact assessment process for the Pluto LNG Development. The key environmental effects predicted at sensitive marine receptors within Dampier Archipelago include:

- light attenuation effects to benthic habitats associated with elevated concentration of suspended solids
- smothering effects to benthic habitats from sedimentation at spoil disposal grounds
- direct loss of habitat from dredging activities
- smothering effects to sensitive species from sedimentation of particles re-suspended by dredging activities, in particular from propeller wash and from spoil disposal activities
- physical impact on the benthic biota from physical disturbances associated with construction activities including anchor damage and blasting activities
- physical impact on marine fauna associated with dredging and spoil disposal activities including blasting activities
- detrimental effects on the marine environment from accidental spillage of sewage, and hydrocarbons including inappropriate disposal of solid wastes
- accidental introduction of marine pest species from vessel hulls and ballast water
- disturbance to existing port user groups including, recreational users and existing industry.

1.4 Legal and Other Requirements

The dredging operations will be conducted in a manner that is consistent with relevant state and Commonwealth and international conventions. This includes:

- *Environment Protection (Sea Dumping) Act 1981* (Cwth)
- Environment Protection (Sea Dumping) Regulations 1983 (Cwth)
- *Environment Protection and Biodiversity Conservation Act* 1999 (Cwth) (EPBC Act)
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwth)

- Australian Quarantine Regulations 2000 (Cwth)
- *Environmental Protection Act 1986* (WA)
- *Pollution of Waters by Oil and Noxious Substances Act 1987* (WA)
- *Port Authorities Act 1999* (WA)
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 7/78).

Other relevant guidance will be considered including the National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEEC/ ARMCANZ 2000) and the National Ocean Disposal Guidelines for Dredged Material (EA 2002) to manage the environmental impacts associated with the proposed Development. In addition, dredging will be undertaken in accordance with Woodside's Health Safety and Environment policies and requirements.

It is noted that *The Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives* was released in June 2006 (DoE 2006a). This document establishes an Environmental Quality Management Framework (EQMF) and presents the EPA's interim set of environmental goals (Environmental Values and Environmental Quality Objectives) and spatially allocates these goals (Levels of Ecological Protection) for state waters of the Pilbara coast (DoE 2006a).

The EQMF establishes five Environmental Values relevant to the Pilbara coastal waters. The 'Ecosystem Health' value is a fundamental value and comprises four different Levels of Ecological Protection. These Levels are allocated based on specific target environmental quality conditions and range from *Low* for existing industrial discharges, *Medium* for existing developed areas including shipping berths and spoil grounds, *High* for unzoned areas including port areas through to *Maximum* for areas of environmental significance.

It is acknowledged that the Levels of Protection have been spatially allocated to Mermaid Sound and while a comprehensive set of Environmental Quality Criteria on which these Levels of Protection will be based has yet to be formally established, they are likely to be based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000).

2. Existing Environment

A detailed description of the existing marine and social environment within Dampier Archipelago is provided in **Section 6** and **Section 10** of the Draft PER. These sections of the Draft PER describe the physical marine environment within Mermaid Sound including sediment characteristics, hydrography and oceanographic conditions, as well as marine ecological features including sensitive marine species (*Commonwealth EPBC Act* listed species), benthic primary producer species and migratory species. **Section 10** of the Draft PER describes the existing port users including industry, shipping, commercial and recreational fisheries and tourism and recreational pursuits.

Currently the key environmental sensitivities within the Dampier Archipelago broadly comprise:

- intertidal and subtidal coral reef – the Dampier Archipelago contains 216 species of corals
- mangrove communities – a total of seven mangrove species are known to exist in the Archipelago
- seagrass and macroalgae – nine species of seagrasses are sparsely distributed throughout the Archipelago, occurring in low abundance on shallow sandy sediments in sheltered areas and large bays
- filter feeding communities and sponge garden habitat – the Dampier Archipelago contains 275 sponge species, of which 20% are limited to Western Australia
- sea turtles –four species of sea turtles are known to nest on beaches within the Dampier Archipelago and migrate through the areas including:
  - green turtle (*Chelonia mydas*)
  - hawksbill turtle (*Eretmochelys imbricata*)
  - flatback turtle (*Natator depressus*)
  - loggerhead turtle (*Caretta caretta*)
- dugongs – the EPBC listed dugong (*Dugong dugon*) is associated with sheltered bays, mangrove channels and seagrass habitat in Dampier Archipelago
- dolphins and whales – a number of dolphin and whales species have been observed in the Pilbara region
- shorebirds and seabirds – various species nest on the islands within the Dampier Archipelago
- recreational fishing and tourism.

3. Project Description

3.1 Pluto LNG Development

The Pluto LNG Development is described in detail in **Section 4** of the Draft PER. The marine components of the Development within Dampier Archipelago will comprise:

- a jetty and causeway
- an off-loading berth capable of safely berthing the LNG and condensate tankers
- a waste water discharge pipeline into Mermaid Sound
- a pipeline system consisting of trunkline and MEG pipeline
- a dredged navigation channel consisting of a channel, turning basin and berth pocket
- spoil disposal grounds.

4. Numerical Modelling of Dredge and Disposal Plumes

Numerical modelling of movement of suspended solid introduced into the water column during dredging related activities has been undertaken as part of preparation of the Draft PER. The modelling results, and interpretation, are summarised in **Section 7.9** of the Draft PER.

5. Historical Effects of Dredging

A description of dredging in Mermaid Sound is presented in **Section 7.9** of the Draft PER. Dredging and dredge spoil disposal operations commenced in the 1960s; a number of additional dredging operations have been undertaken since in conjunction with industrial development in the region. An historical summary of dredging operations in Mermaid Sound is provided in **Table 1**.

Table 1 Summary of Previous Dredging Activities Within Mermaid Sound

Proponent	Year	Location of Dredging	Volume of Dredge Material (m^3)
Hamersley Iron	1965	Capital Dredging of Shipping Channel to Parker Point	2 500 000
Hamersley Iron	1968	Deepening of Shipping Channel to Parker Point	1 500 000
Hamersley Iron	1970–71	Widening of Shipping Channel and Extension of the Channel to East Intercourse Island Facility	760 000
NWSV	Dec 1981–Sep 1982	North Rankin A Platform to NWSV Karratha Gas Plant	280 000
Hamersley Iron	1981	Deepening and Widening of Shipping Channel to Parker Point	400 000
NWSV	1981	King Bay Supply Base	1 200 000
NWSV	Nov 1981–Dec 1982	Island Berth and Materials Offloading Facility	140 000
Hamersley Iron	1985	Maintenance Dredging of East Intercourse Island Berth and Shipping Channel	Volume unknown
NWSV	Oct 1986–Jun 1987	LNG Shipping Channel	6 600 000
NWSV	Aug 1989–Sep 1989	Maintenance Dredging of LNG Shipping Channel	149 700
Hamersley Iron	1989	Maintenance Dredging of Shipping Channel	350 000
Hamersley Iron	1991	Maintenance Dredging of East Intercourse Island Berth	Volume unknown
NWSV	1994	Berthing Pocket for LNG Ships	700 000
Hamersley Iron	1998	Capital Dredging of Shipping Channel	2 000 000
Hamersley Iron	1998	Maintenance Dredging around Berths	800 000
Hamersley Iron	2000	Minor Dredging around Berths	5000
NWSV	2002	Trunkline System Expansion Project (TSEP)	2 600 000
Dampier Port Authority	Jan–Jun 2004	Dredging of Shipping Channel, Swinging Basin and Berths	4 500 000
Hamersley Iron	Apr–Aug 2004	Capital Dredging for Parker Point Upgrade	3 100 000
Hamersley Iron	Oct–Nov 2004	Maintenance and Capitol Dredging for Extension of Parker Point Upgrade	500 000
NWSV	May 2005–Oct 2006	LNG Phase V	3 300 000
		Total	> 31 434 700

6. Management

6.1 Overview

All activities associated with the proposed dredging and dredge spoil disposal operations will be managed to reduce actual and potential environmental impacts to ALARP. This will be achieved through the implementation of a number of management measures related to the operation of the dredge vessels:

- quarantine management – including ballast water and vessel hull management
- waste management – covering management of solid, liquid and hazardous waste
- hydrocarbon management – including refuelling and Oil Spill Contingency Planning (OSCP)
- water quality management – during spoil transport and disposal to sea at spoil grounds
- vessel operations – including vessel movements and collision prevention.

6.2 Ballast Water and Marine Pest Management

Management measures will be implemented to prevent the potential introduction of marine pest species either within ballast water or attached to the hull or enclosed spaces of vessels associated with the dredging programme. The management of ballast water will be in accordance with Australian Ballast Water Requirements and the Australian Quarantine Regulations 2000 (Cwth).

Vessel Inspections: All vessels associated with the dredging programme that are to be mobilised from a location outside of the bioregion will be inspected by a suitably qualified person prior to mobilisation to Dampier.

- *Pre-mobilisation Inspections:* An inspection is to be carried out prior to mobilisation to Dampier by a suitably qualified person or agency to ensure that the hull is clean and free of attached introduced marine organisms prior to transit to Dampier. The inspection will also ensure that all internal compartments, dredge pipelines and areas of the vessel that are exposed to marine sediments, have been thoroughly cleaned and flushed through with clean sea water prior to departure from an overseas port.
- *Inspections on Arrival to Dampier:* Vessels with last port of call outside of the bioregion will be inspected upon arrival into Dampier by an appropriately qualified person. Should evidence of material be observed from previous dredging operations, the vessel will be sent immediately offshore for flushing beyond the 12 nm limit and in water depths of greater than 200 m.

Vessel Discharges: All discharges of ballast water will occur in accordance with the Australian Ballast Water Requirements.

6.3 Hydrocarbon Management

As part of day-to-day dredging operations diesel fuel, oil, grease and certain chemicals are handled on a regular basis. The handling of hydrocarbons represents an environmental risk to the marine environment in the event of an accidental spillage. The key areas of risk associated with dredging activities include:

- refuelling of the dredge vessel
- storage and handling of oils, grease and chemicals
- breakdown of grease on moving parts, including cutter ladder and spud carriage.

6.3.1 Refuelling

Predictive modelling of a diesel spill (2.5 m^3) from a dredge vessel refuelling within Mermaid Sound for the Draft PER (**Section 7.10** of the Draft PER). In the unlikely event of a diesel spill, the modelling indicates that diesel will evaporate rapidly (hours) and is unlikely to have a significant impact on sensitive marine receptors within Mermaid Sound.

Refuelling management procedures that will be implemented to reduce the probability of a spill include the following:

- Refuelling within Dampier Port Authority (DPA) limits will be conducted in accordance with all DPA requirements.
- Onboard spills such as engine oil and below deck spills will be captured (catchment lips around potential spill areas), mopped up, containerised and sent to shore for recycling/disposal. Spills will not be discharged to the ocean.
- Any fuel and oil spills within Dampier Port limits will be managed in accordance with DPA's oil spill arrangements and procedures with support from Woodside's Oil Spill Contingency Plan (ERP-3210).
- The OSCP (ERP-3210) is supported by trained and experienced personnel, extensive dispersant, materials and equipment stockpiles at the King Bay Supply Base' Woodside has the capability to initiate real-time oil spill fate and trajectory modelling using the OILTRAK and OILMAP models.
- The dredge master will maintain a Ship Board Oil Spill Response Plan (SOSRP) for each dredge vessel in accordance with the requirements of MARPOL 73/78. This plan will outline responsibilities, specify procedures and identify resources available in the event of an oil spill. The SOSRP will be supported by Woodside's OSCP (ERP-3210).
- Any fuel or oil spills must be reported using the incident reporting system.

6.3.2 Storage of Oils, Grease and Chemicals

Oils, greases and chemicals will be securely stored onboard the dredge vessels in marked containers. Hydrocarbons stored above deck will be bunded with 110% capacity of the total volume of oils, greases and chemicals being stored to prevent leaks. Spill response kits will be provided and located in close proximity to storage and operational areas. The Master/ Captain will be responsible for checking all storage and operational areas on a daily basis to ensure these materials are safely secured.

6.3.3 Breakdown of Grease on Moving Parts

Dredging vessels typically use greases to lubricate the cutter shafts and spud carriages which are in contact with the water. There is subsequently a risk of small quantities of grease being discharged into the water. Measures that will be implemented to mitigate impacts include:

1) A work instruction will be prepared by the dredge operator that will outline practical guidelines for crew members to follow to reduce potential discharges into the marine environment.
2) Periodic monitoring of automatic greasing machines will be undertaken to minimise the build up of grease, whilst not compromising the functionality of the moving parts.
3) The dredge vessels will be equipped with scoops or nets ready to collect grease discharged into the water.
4) Where practicable, biodegradable greases will be used.

6.3.4 Spill Response and Reporting

The dredging contractor will develop and implement an OSCP for the period of the dredging operations. This will be consistent with the DPA OSCP and Woodside's OSCP and appended to this management plan.

6.4 Waste Management

6.4.1 Solid Wastes

All solid wastes, such as packaging and domestic wastes, will be segregated into clearly marked containers prior to onshore disposal. No plastics or plastic products of any kind will be disposed of overboard. No domestic waste (that is, cans, glass, paper or other waste from living areas) will be discharged overboard. No maintenance wastes (for example, paint sweepings, rags, deck sweepings, oil soaks, machinery deposits, etc.) will be disposed of overboard. Where possible, spent oil and chemical containers will be returned to the supplier for reuse or recycling.

Waste items will be stored in designated areas for recycling or disposal onshore by a licensed contractor and taken to the Shire of Roebourne landfill near to Karratha.

6.4.2 Sewage and Putrescible Waste

Vessels operating inside Dampier Port limits will not discharge sewage or putrescible waste into the marine environment, unless it has been treated by a system that has been accepted by DPA as meeting the requirements of an IMO-approved sewage treatment system.

In the event that dredge vessels are operating beyond the Dampier Port limits, sewage and putrescible wastes will be managed in accordance with MARPOL 73/78 Annex IV and *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwth). Sewage from an IMO-approved sewage treatment plant may be discharged at any location, beyond the Dampier Port limits, providing the effluent does not produce visible floating solids nor cause discolouration of the surrounding water.

6.4.3 Hazardous Wastes

Hazardous wastes such as absorbent material used for oil or chemical spillages will be disposed of at a licensed hazardous waste facility.

Disposal of any oil sludges/slops in port must be recorded in the vessel Oil Record Book (a requirement under MARPOL 73/78).

6.5 Vessel Movement Management

The movement of the dredge vessels in close proximity to existing port infrastructure including DPA loading wharfs will be carefully coordinated between the DPA and dredge contractor. In the event of a cyclone or other severe weather conditions, the vessel contractor will seek advice from the DPA on safe locations for anchorage either within or beyond the Dampier Port limits.

6.5.1 Collision Prevention

The dredging schedule will be designed to prevent vessel collision. The Dampier Port users are comprised of a number of industries including NWSV, Hamersley Iron, Dampier Salt and Burrup Fertilisers. The vessel contractor will provide the DPA with a programme of the dredge schedule two weeks prior to dredging commencement. Within this period, the DPA will issue Notices to Mariners to advise all other shipping activity of the dredging vessels intended movements.

When dredging is underway, the DPA will advise incoming vessels into Dampier Port of the location of the dredge vessels, spoil disposal grounds under use at the time of dredging and any obstructions associated with dredging, including floating or submerged pipes. Collision prevention procedures will be discussed and agreed between the dredging contractor, Woodside and the DPA.

The location of the northerly extension to spoil ground A/B within Mermaid Sound and the offshore spoil ground 2B will be provided to AMSA for inclusion on Australian navigation charts.

6.5.2 Mitigation Measures for Protection of Marine Mammals and Sea Turtles

6.5.2.1 Dredging

Prior to commencement of dredging activities, the dredging contractor and crew will receive induction that, among other things, describes the location of sensitive marine mammal and sea turtle habitat in relation to proposed dredging activities and seasonal environmental sensitivities, such as the humpback whale migration and coral spawning events.

The use of sea turtle deflection devices will be considered for use on trailer suction hopper dredges (note that these devices are not considered feasible for application to cutter suction dredges). An alternative to turtle deflectors, which will also be considered, are Jetting Systems. These systems force water and marine fauna (in particular sea turtles) away from the drag head, thereby avoiding any direct contact. Upon commencement of dredging, the jetting system will be switched on, prior to engaging the dredge pumps. When the dredging operation stops, the dredging pumps will be switched off prior to switching off the jetting system.

6.5.2.2 Dredge Spoil Disposal

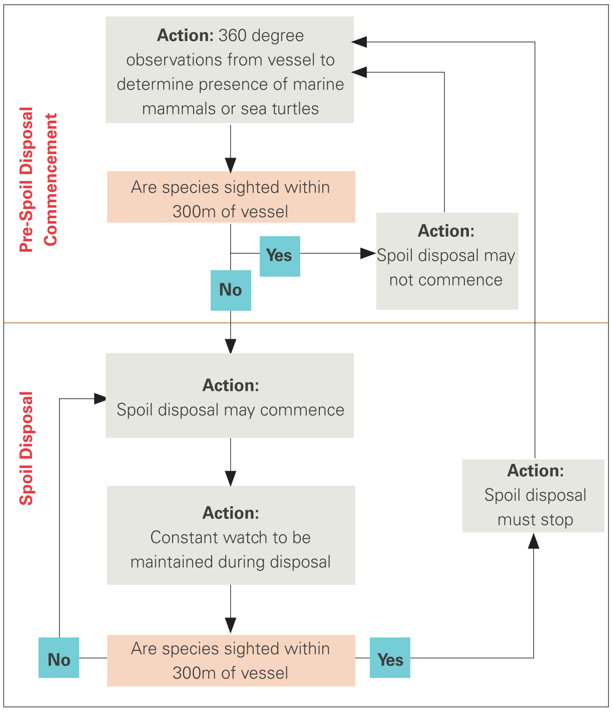
The following procedures will be undertaken to protect marine mammals and sea turtles that are present within 300 m of any point at which disposal activities are planned (**Figure 1**).

- Prior to commencement of sea disposal activities, the dredging contractor will check for the presence of marine mammals and sea turtles within 300 m radius of the dredge vessel.
- Disposal activities may only commence if no marine mammals or sea turtles have been observed within 300 m of the dredge vessel for ten minutes immediately preceding commencement of disposal operations.
- Should any marine mammals or sea turtles be observed within 300 m of the vessel prior to and during disposal activities, disposal activities must stop and may not recommence until i) the animal/s are seen to move >300 m from the vessel ii) the animals have not been seen for >20 minutes duration or iii) the vessel moves to a location >300 m from the observed animals.

The dredging contractor will document any incidents that occur during disposal operations that result in injury or mortality of marine mammals and sea turtles. Details of the incident including time and date of incident, cause of injury/ mortality and the species (if known) will be recorded and reported to the Western Australian Department of Environment and Conservation (DEC) and the DEH.

Sightings of marine mammals and sea turtles will be maintained in the vessels daily log book.

Figure 1 Procedure to Protect Marine Mammals and Sea Turtles During Spoil Disposal



6.5.3 Scheduling and Communications

Prior to dredging activities commencing, the dredging contractor will notify the DPA and other port users of the proposed dredging programme and operations. This will be undertaken at least two weeks prior to schedule commencement. During this period the dredging contractor will seek advice from the DPA on scheduled vessel movements in the vicinity of the proposed dredge location. The intention will be to conduct dredging of the navigation channel, berth pocket and turning basin without interference to other commercial vessels.

The dredge vessels will maintain constant radio communications with the DPA to ensure that the DPA are fully informed of planned vessel movements and advise other port user groups where necessary.

6.6 Water Quality Management

The focus of the environmental management efforts will be to minimise the generation of sediment plumes and turbidity within the water column. To do this effectively, the dredging programme will be carefully planned by the dredging contractor, selecting the most appropriate work method and performing the dredging operations in the shortest possible timeframes. Particular strategies that will be implemented to minimise generation of turbidity from the dredging and dredge spoil disposal operations will include the following:

- Dredging operations will be prevented during coral mass spawning events in areas where activities may adversely affect corals or coral larvae settlement.

- The spoil grounds will be located away from sensitive areas and utilising previously disturbed spoil grounds as far as practicable.
- The dredging method will include disposal of spoil into spoil grounds within Mermaid Sound for the shortest period, practicable.
- The method of dredging and transporting spoil disposal is based on a combination of cutter suction dredging and pick up by trailer suction hopper dredge.
- Disposal of spoil into spoil ground A/B and a northerly extension of this area will be restricted to a relatively small defined area within the overall limits of this area. This will minimise turbidity levels to a small area as opposed to disposal throughout spoil ground A/B.
- The majority of spoil will be disposed into an offshore spoil ground located outside of Dampier Port. This will minimise elevated turbidity levels experienced at sensitive coral habitat and other benthic habitats within the Dampier Archipelago.

6.6.1 Environmental Quality Objectives

The environmental quality objectives relating to water quality during dredging and disposal activities are to:

- minimise impacts on benthic primary producer habitats within the Dampier Archipelago
- minimise the spatial extent, duration and magnitude of turbidity and sedimentation from dredging operations
- implement an effective baseline monitoring programme with nine months of baseline data to be used in the implementation of effective coral and water quality monitoring programmes (**Section 7**), addressing the Environmental Quality Management Framework (DoE 2006a)
- minimise disturbance to existing port users including commercial and recreational user groups
- minimise impact to existing industry.

6.6.2 Water Quality Mitigation Measures

A suite of mitigation measures will be implemented by the dredging contractor to reduce turbidity effects during all phases of the dredging operations. Examples of management measures that will be applied include:

- reducing impacts associated with propeller wash to ALARP by targeting dredging of shallow areas to times when the dredge vessel is empty and/or coincide with high tide
- utilising favourable weather, tide and current conditions as far as reasonably practicable to limit effects to sensitive areas
- reducing trailer suction hopper dredge overflow and overflow of barges through operational procedures
- disposal of spoil further away from the potential area of impact sites within the spoil areas; taking prevailing weather conditions into consideration to avoid plumes being forced towards sensitive areas
- postponing dredging activities, including spoil disposal in areas that may cause adverse effects to coral reef communities during coral mass spawning events
- preventing spoil disposal operations should marine mammals or sea turtles be present within 300 m of the dredge vessel (**Section 6.5.2**)
- identifying opportunities for recycling dredge spoil material as far as reasonably practicable at the time of dredging.

These measures will be continually reviewed and if necessary modified to improve environmental performance. In addition, the results of ongoing water quality monitoring will determine the need for implementation of additional measures should certain trigger levels be exceeded. This is discussed further in **Section 7** of the Draft PER.

7. Monitoring

7.1 Aim of Monitoring Programmes

A suite of monitoring programmes will be implemented before, during and after completion of the proposed dredging programme. The overarching aim is to limit potential environmental impacts associated with dredge related activities, in particular impacts to coral communities and other sensitive habitats.

7.2 Impacts to be Monitored

Unavoidable impacts to benthic primary producer habitat that are predicted from the Pluto LNG Development are outlined in detail in the Draft PER (**Section 7**). These impacts include localised removal of coral habitat and significant degradation in coral habitat directly adjacent to the proposed jetty due to sedimentation. While the areas of degradation due to sedimentation may not suffer a complete loss of coral habitat, they are at high risk of inundation by sediments causing intense, localised mortality. Recovery is possible, but, independent of active rehabilitation, will depend on the availability of hard substrate for larvae settlement and influx of larvae from surrounding habitats.

The evaluation of environmental impacts presented within the Pluto LNG Development Draft PER has identified acute sedimentation as the main cause of mortality at affected coral communities close to the dredging and spoil disposal locations. Other impacts include lower levels of continual sedimentation, and shading caused by suspended solids. These impacts may not have any immediately visible effect, but may lead to deterioration of the health of benthic biota.

The following monitoring programmes and surveys have been designed to address both acute and chronic impacts in protecting the ecological, social and commercial values within the Dampier Archipelago from the effects of predicted disturbances associated with the proposed dredging activities, including prevention of losses of benthic primary producer habitat outside the expected areas of unavoidable loss identified in the Draft PER.

7.3 Monitoring Programmes

The impacts from the dredging and spoil disposal activities will be monitored through six inter-related surveys and monitoring programmes.

- baseline pre-dredge study
- predictive forecasts
- monitoring of 'lead' indicators
- monitoring of 'lag' indicators
- post-dredging survey of long term effects
- monitoring of communication and reporting.

7.3.1 Baseline Pre-dredge Study

The aim of the baseline survey is to collect sufficient pre-dredging baseline information on sedimentation rates, water quality and coral health in Mermaid Sound to establish trigger levels for management purposes. The baseline pre-dredge study will consist of two sub-surveys, namely coral health and sedimentation monitoring surveys:

Coral health: The baseline survey of coral health will collect information on coral cover and sub-lethal parameters such as bleaching and mucus production at various sites both within and outside Mermaid Sound.

Sedimentation: The sedimentation baseline survey will use remote sedimentation logging meters to collect sedimentation data on various sites in and outside Mermaid Sound. These meters will continuously record sedimentation over a short-term time at approximately 10 minute intervals on a data logger for periodic recovery and downloading. In addition the loggers record turbidity and light intensity.

The surveys commenced in August 2006 with the aim of collecting data for nine months prior to the commencement of the Pluto LNG Development dredging programme. They will establish baseline exposure levels of sedimentation rates during tidal cycles and across seasons. The use of this data will be fundamental in the development of sedimentation trigger values for the reactive monitoring programme.

The baseline study is described in detail in **Appendix A**.

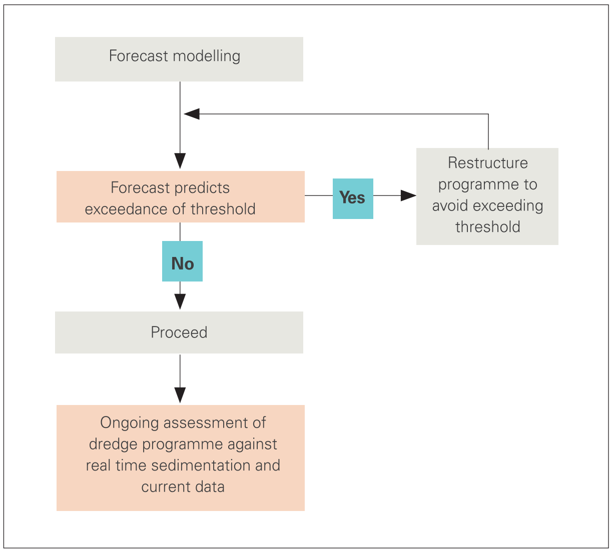
7.3.2 Predictive Forecasts

The objective of the predictive forecasts is to predict sediment plume dispersion into sensitive areas using short-term forecast data (**Figure 2**). This will be used to plan dredging activities in close proximity to these areas to coincide with optimal conditions as far is practicably possible, when close to sensitive areas.

Forecast modelling of plume dispersions will be obtained using a numerical model simulating dredging activities with forecast data of weather and current conditions coupled with planned dredging and spoil disposal activities. The model output will provide an indication of the predicted dispersion of sediments into the water column and sedimentation rates in the vicinity of the daily dredge locations. This will assist in identifying those days and activities which are predicted to result in significant impacts on corals communities.

The model will be assessed prior to and throughout the dredge and spoil disposal programme against real time data on sedimentation and current movements collected both during the baseline survey as well as during the dredging programme. Details will be developed for the detailed DSDMP.

Figure 2 Predictive Modelling Approach



7.3.3 Monitoring of Physical and Biological Indicators

The aim of the monitoring programme is to provide early detection of physical stressors (sedimentation and turbidity) and biological indicators (corals) that can be used for active management to avoid or minimise potential environmental impacts associated with the dredging programme.

Monitoring of sedimentation, turbidity and light intensity on a real-time basis provides an early indication of potential stressors that may result in biological impacts, as such they are referred to as a 'lead indicators'. Monitoring of coral health parameters and coral mortality provides a measure of impact after the event and these are referred to as 'lag indicators'.

It is proposed to utilise a combination of lead and lag indicators to monitor, and where necessary respond to, impacts of the dredge programme.

7.3.3.1 Lead Indicators

Real time monitoring of sedimentation, turbidity and light intensity will enable identification of potential elevation of stressors before they accumulate to the point where biological impacts may occur. The monitoring of lead indictors will be a continuation of the baseline sedimentation study but with increased frequency of data downloading. The sedimentation loggers will be kept at the same sites as for the baseline survey, unless there is an obvious advantage in relocating them due to changes in the dredging programme.

7.3.3.2 Lag Indicators

The coral monitoring will be a continuation of the baseline coral health monitoring, using the same techniques but with increased frequency and inclusion of additional sites.

A total of 13 sites for coral health monitoring are proposed based on a review of the current dredging programme and predicted and potential impacts (**FigureB1**; **Table B1**). The reactive monitoring will collect data on both degree of bleaching and coral cover on a roster basis with immediate analysis of data to detect decreasing trends in coral cover. Timing and duration of surveys will be tailored to period of exposure to dredge-related activities:

Certain sites outside Mermaid Sound will be monitored for reactive purposes once spoil disposal into the offshore spoil ground 2B has been initiated. The timing of monitoring at each site will be described in the final version of the DSDMP once the dredging programme has been established in detail.

7.3.3.3 Reactive Management

The reactive management is a planned process for responding to possible monitoring outcomes in order to avoid or minimise potential environmental impacts (**Figure 3**). The reactive management is based on a tiered response to a combination of lead and lag indicators and take consideration of:

- frequency of potential disturbance
- reversibility of stressor, that is how successful intervention measures would be in preventing biological impact
- natural variability.

The trigger values for lead indicators, sedimentation and turbidity, are to be based on the results of baseline monitoring at the sites.

The first tier trigger value (T_1) is when measured conditions exceed the 95th percentile of all records of natural variability for the season at that location. The second tier trigger value (T_2) is when measured conditions exceed the 99th percentile of all records of natural variability for the season at that location.

An element of duration and/or recurrence shall be included in the trigger values as this will allow for response to repetitive stressors, for example not to exceed the 95th percentile for more than 5 days within any 30 day period. However, it will be necessary to view the baseline dataset in order to determine the most meaningful value.

The threshold values for lag indicators, coral health and mortality, will also be based on the results of baseline monitoring at reference and impact sites. Tier 1 trigger value (T_1) for lag indicators are when the net loss is equal or greater than 10% and Tier 2 trigger value (T_2) for lag indicators are when the net loss is equal or greater than 20%.

7.3.3.4 Additional Monitoring

During the nearshore dredging activities sedimentation rates in the vicinity of the uplift area will be monitored in addition to the sedimentation rates obtained using the logger on site DPAN as outlined in **Appendix A**. Further details on this additional sedimentation monitoring will be developed as the dredging programme progresses and data from the baseline study becomes available to guide further efforts on obtaining data on sedimentation rates.

7.3.4 Post-dredge Baseline Survey

Following the completion of dredging and spoil disposal, the coral monitoring will continue to run to establish any delayed effects from sedimentation or light deprivation, and monitor for signs of recovery. The post-dredge baseline survey will essentially be a continuation of the reactive coral monitoring programme, with changes only to the frequency of surveys, and the number of sites surveyed. All sites will be surveyed at least once post-dredging, and continue (whichever comes first):

- until coral cover has not declined significantly for two consecutive surveys
- until a new activity (such as a new dredging project) is likely to impact on a site
- for two years after completion of dredging.

Sites outside the zone of impact (reference sites) will be surveyed only once after end dredging, and discontinued unless there has been a significant decline in coral cover since the last monitoring survey.

7.3.5 Summary of Proposed Monitoring Techniques

The parameters to be monitored during the coral and sedimentation surveys and a justification for their collection are outlined in **Table 2**. The framework for implementation of the reactive monitoring is illustrated in **Figure 3**. The management actions to be taken in response to any combination of lead and lag indicator measurements are summarised within the boxes contained in the matrix. For example, an observed exceedance of Tier 1 of the lead indicator would result in an increase in intensity of monitoring of coral health and mortality, should this show an increase above the lag indicator Tier 1 trigger value the management response would be to stop activities that impact that area, further increase lag indicator intensity and determine source of impact.

Figure 3 Tiered Management Response Matrix

	<T1	≥T1	≥T2
<T1	Continue	• Continue • Increase lag indicator intensity	• Stop activities that impact area • Increase lag indicator intensity
≥T1	• Continue • Increase lag indicator intensity	• Stop activities that impact area • Increase lag indicator intensity	Stop activities that impact area until indicators are outside zone
≥T2	• Stop activities that impact area • Increase lag indicator intensity	Stop activities that impact area until indicators are outside zone	Stop activities that impact area until indicators are outside zone

7.3.6 Monitoring of Management System

The objectives of monitoring the management system is to ensure that all personnel are fulfilling their responsibility and that all relevant information is being collected, passed on to the appropriate persons, and that all exceedence of trigger levels are acted upon in accordance with the detailed DSDMP.

The monitoring of the management system will include, but will not be limited to the following:

- all personnel are suitably qualified for their tasks and responsibilities
- all personnel are briefed on their roles during induction sessions
- the predictive model is run on a regular basis to predict optimal dredging and spoil disposal operation when operations occur in close proximity of sensitive marine habitats
- the findings of the predictive model are communicated to the dredging contractor for daily dredge programme planning
- the environmental monitoring takes place in accordance with the detailed version of this DSDMP
- all collected information is reported to the appropriate staff responsible for data analysis and initiation of management actions, should trigger levels be exceeded

Table 2 Summary of Proposed Monitoring Techniques

Monitoring Parameters	Purpose of Data Collection
Baseline Pre-dredge Study (sedimentation, turbidity and light intensity at selected sites)	Establish conditions prior to implementation of dredging
	Enhance knowledge of variability in sedimentation in Mermaid Sound to set trigger values for management purposes
	Collect data for development of sedimentation trigger levels (in conjunction with coral health data)
	Calibration of predictive model
Baseline Pre-dredge Study (coral health at selected sites)	Establish baseline coral cover prior to impact
	Collect data for establishment of sedimentation trigger levels (in conjunction with sedimentation data)
Forecast Modelling	Modelling of plume dispersions with forecast meteorological and oceanographic conditions. Modelling will provide an indication of sediment dispersion on each day of dredging and days on which corals are likely to be significantly impacted.
Reactive Monitoring (sedimentation, turbidity and light intensity at impact sites)	Reactive monitoring of water quality; can trigger Tiered management system
	Verification of forecast model
	Verification of coral sedimentation trigger levels and investigation of stress levels (in conjunction with coral health data)
Reactive monitoring (sedimentation, turbidity and light intensity at reference sites)	Verification of forecast model
	Comparison to levels at impact sites
	Facilitate interpretation of coral health data
	Verification of coral sedimentation trigger levels and investigation of stress levels (in conjunction with coral health data)
Reactive monitoring (coral health at impact sites)	Reactive monitoring of net mortality; can trigger Tiered management system
	Verification of coral sedimentation trigger levels (in conjunction with water quality data)
Reactive monitoring (coral health at reference sites)	Ability to estimate net coral mortality at impact sites by comparing to the mortality at reference sites
	Investigate natural variation in coral cover (in conjunction with background water quality data)
Post-dredging survey (coral health on all sites)	Investigate time-lagged and/or chronic impacts
	Estimate gross coral mortality during the entire programme and assess cumulative impact

- appropriate communication exists between the environmental impact manager, the predictive program manager and the dredging contractor manager to ensure compliance with optimal daily operations and compliance with management measures
- incident reporting, information on monitoring findings and management actions are communicated to the appropriate authorities within set time stipulated in the detailed version of this DSDMP.

The details and allocation of responsibilities will be developed and included in the detailed version of this DSDMP.

7.3.7 Management Options

Management of Indirect Impacts

A number of preventative measures will be implemented prior to, during and following the dredging operations to reduce potential indirect and direct environmental impacts.

During the dredge and spoil disposal programme predicted impacts and/or exceedence of set tiered trigger levels will result in the implementation of mitigation measures. These measures will need to be agreed to by the dredging contractor, and clearly and timely communicated to the dredging manager throughout the programme. These measures include:

- reducing propeller wash by maintaining keel clearance by, as far as reasonably practicable, dredging shallow areas on high tides and/or when hoppers are empty
- utilising favourable weather, tide and current conditions as far as reasonably practicable to limit effects when dredging or disposal take place in close proximity to sensitive areas
- reducing trailer suction hopper dredge overflow and overflow of barges through operational procedures
- disposal of spoil further away from the potential area of impact sites within the spoil areas, as far as reasonably practicable
- dredging and disposal sequence to be ceased until a number of conditions can be satisfied according to the tiered management system.

Management of Direct Impacts

Direct impacts to seabed habitats will occur during the construction of the navigation channel, jetty and trunkline landfall. This will cause direct impact to coral communities, as described below.

The construction of the causeway / jetty and trunkline landfall (gas trunkline Option 2) at Holden Point will remove approximately 20 000 m^2 of coral habitat. These new structures will provide substrate for coral to colonise as has been observed elsewhere in Mermaid Sound (Mscience 2005a).

8. Reporting

8.1 Frequency of Reporting

Reporting will be undertaken with respect to the following:

- baseline pre-dredge study
- reactive monitoring during the dredging programme
- post-dredge survey.

8.1.1 Baseline Pre-dredge Survey Reporting

The baseline survey will be undertaken for nine months between August 2006 and June 2007. A report will be prepared and will include:

- a summary of the findings from the baseline study
- interpretation of baseline data
- definition of trigger levels to be applied during the reactive monitoring programme.

This report will be provided to the relevant regulatory agency and made publicly available. Preliminary data will be made available to the regulatory authorities during the baseline study subject to prior satisfactory preliminary interpretation of the obtained data in liaison with the developer of the sedimentation logger for the purpose of preliminary release.

8.1.2 Reactive Monitoring Reporting

The reactive monitoring programme will be conducted over the duration of dredging and the reporting aspects will include:

- Summary report of sedimentation, turbidity, light conditions and coral monitoring results, including any trigger value exceedance and actions taken in response, to the regulatory agency, and made publicly available, on a quarterly basis.
- Immediate reporting of any exceedances of coral trigger levels 1 or 2 to the regulatory agency.
- A final report provided within six months after termination of the reactive monitoring to the relevant regulatory agency and made publicly available.

8.1.3 Post-dredge Reporting

A post dredge survey will be conducted following completion of the dredge. The final report will document condition of affected benthic habitat after cessation of dredging activities. This report will compare the findings of the post-dredge survey to the baseline survey findings. The report will be provided to the relevant regulatory agency and made publicly available.

Appendix A

Baseline Study on Sedimentation and Coral Health

A.1 Scope of the Baseline Study

The objective of the baseline study is to enhance the understanding of the ambient sedimentation and light regimes under which the coral communities in Mermaid Sound exist. This knowledge will form the basis on which to develop sedimentation trigger levels for use in the reactive monitoring programme.

To accomplish the development of such trigger levels, a baseline study will be carried out for nine months between August 2006 and June 2007, prior to commencement of dredging. This will involve the continuous collection of sedimentation, turbidity, light intensity and temperature data coupled with coral monitoring at various locations within and outside of Mermaid Sound. Sediment from each study sites will be characterised and the relationship between TSS concentration and turbidity will be investigated in an experimental set-up.

A.2 Background Issues

Sedimentation and, to a certain extent, light attenuation have been identified as the key parameters likely to cause deterioration in coral health, and potentially leading to mortality (**Section 7.9** in the Draft PER). **Table A1** provides a definition and summary of these impacts and their potential effect on coral communities.

The degree of impact caused by sedimentation and light deprivation will depend on:

- the magnitude of sedimentation and/or light attenuation
- the duration of the event
- the reoccurance of the events
- the pre-event status of the coral.

The inter-relationship between these parameters, including the combined effects of sedimentation and light deprivation, is not well understood. Some studies have documented sub-lethal effects, providing some indications of sediment levels affecting adult metabolism (APASA and SKM 2006). However, these studies do not necessarily apply to species and conditions found in Mermaid Sound and therefore the issue of adaptation of corals to past levels of sediment are critical when developing trigger levels for management purposes. Some species and growth forms are substantially more tolerant than others. Furthermore, some species appear to be capable of adapting their physiological response to increased sedimentation or low light irradiance (Anthony and Connolly 2004).

Table A1 Light Attenuation and Sedimentation Definitions and Summary of Environmental Effects

Parameter	Definition	Potential Impact on Corals
Light attenuation	The decrease in light as it passes through the water layer before striking the organism	Decrease in the amount of energy available for coral metabolism via the photosynthetic pathway of zooxanthellae
Sedimentation	The rate of particles settling out of the water column	Increase in the amount of energy required from the coral to clear off coating sediments – or inundation causing coral mortality by inhibiting process at the tissue-water interface.

A.3 Determination of Trigger Levels

The development of sound trigger levels is paramount for successful management of impacts caused by dredging and spoil disposal. The question of when "a coral" can no longer cope with the ambient levels of sedimentation and light attenuation is complex, as outlined in **Section 7.9** of the Draft PER.

To circumvent the problem of setting thresholds levels where corals will suffer mortality, McArthur et al (2002) proposed to develop trigger levels for a dredging project in Florida based on historic exposure levels to suspended solids. As part of this study, eight months of backscatter data was collected (interpolated as concentration of suspended solids) prior to the dredging programme. It was also used to describe the levels of suspended solids the coral communities could tolerate. The determination of the 95 and 99 percentiles of the intensity, duration and frequency of the recurrence of suspended solids then formed the basis for developing trigger levels for management purposes. As the pattern of suspended solids showed strong winter-summer differences the trigger values were calculated for each season separately. Using an intensity-duration-frequency histogram McArthur et al (2002) suggested the 99 percentile as the 'not to be exceeded' level. They also set trigger levels for action as the 95 percentile intensity for specific durations as frequency not to be exceeded during a season. This approach ensured that the impacts from suspended solids caused by the dredging operation were within 'natural' levels, durations and frequencies.

A.4 Developing Trigger Levels For Mermaid Sound

A similar approach to McArthur et al (2002) will be adopted for development of trigger levels for the dredging activities associated with the Pluto LNG Development. In order to develop target criteria for the protection of coral communities from sedimentation data, it is essential to have a long baseline of reliable data. The strong seasonal variation between weather patterns in winter and spring at Dampier furthermore require baseline data to be collected over at least one set of seasonal conditions relevant to the dredging period. Strong influence of tide in relatively shallow waters requires separate data points within a tidal cycle. The baseline study is therefore aimed to be of nine months duration, encompass both winter and summer conditions, with a time-discrimination finer than the tidal cycle.

After collection the baseline data will be compared to records available of weather, tidal heights and bathymetry to develop a predictive relationship. The frequency of intensity-duration events will be assessed to develop a data distribution capable of forming the basis for trigger levels aimed at preventing exposure to sedimentation levels above normal range of variability at the benthic habitat locations. As this approach has not previously been undertaken in the Dampier Archipelago, it will provide crucial information for the management of future dredging projects as well as for the Pluto LNG Development.

A similar baseline study and monitoring programme was recently undertaken in Queensland, where sedimentation and turbidity loggers were used to collect baseline data and to monitor water quality during dredging. A comprehensive review of the outcomes from this project will be used in the establishment of the Pluto LNG Development trigger levels and the development of the detailed monitoring methodology. The approach of using baseline study data to establish the background variation with associated maximum acceptable levels during dredging is similar to the Environmental Quality Management Framework (DoE 2006a). The Environmental Quality Management Framework and the responsible regulatory authorities will be consulted during the process of establishing trigger levels and developing the detailed DSDMP.

A.5 Methodology

To encompass the objective of collecting sufficient data to develop trigger levels, the baseline study will comprise two sub-surveys, commencing in August 2006. The two sub-surveys will consist of:

- continuous logging of sedimentation, turbidity and light intensity at five sites within and outside Mermaid Sound
- coral transect surveys at eight sites within and outside Mermaid Sound.

A.5.1 Sedimentation, Turbidity and Light Level Survey

For continuous measurement of sedimentation rates the baseline study will utilise newly developed Sediment Accumulation Meters. In contrast to traditional sediment traps, the temporal resolution of the Sediment Accumulation Meter readings is of the order of one hour or less, with a sediment thickness resolution of 20 µm. A plate is mounted above the seafloor and the amount of sediment accumulated on a plate in a given time interval is measured by an Optical Back Scatter (OBS) logger. The relationship between the amount of sediment accumulated and the OBS output reading is known with a 35% error margin. Gaps in field data have previously occurred through fouling of the sensor, burial of the instrument by accumulated sediment under extreme sediment conditions or an unreliable pattern in the OBS sensor signal due to incomplete clearing of the sensor. In these instances, the instrument will be able to provide estimates of turbidity in NTU. The instrument and its use are described in detail in Thomas and Ridd (2005). The logger requires service every four weeks for cleaning, download of data and routine check.

At present, deployment of this instrument has been associated with programmes which have involved its developer. The instrument is not in commercial manufacture, and will be deployed and serviced by a team led by the developer during the Pluto LNG Development baseline study. The developer will be involved with data analysis and interpretation after the baseline survey and throughout the reactive monitoring programme. A similar programme involving the instrument developer is at present being undertaken as part of a dredging operation in Queensland. The outcomes from this programme will feed into the Pluto LNG Development baseline study and monitoring programme.

To investigate the relationship between TSS and turbidity, sediment samples will be collected from each baseline study site. Various concentrations of each sample in an aquarium with associated measurements of turbidity will aid in the interpretation of *in situ* turbidity data obtained during the baseline study. Sediments from each baseline study site will be characterised for reference during the dredging programme, where an influx of foreign sediments to a particular site may or may not be attributed to dredging.

A.5.2 Coral Health and Mortality

Data on coral population dynamics in Mermaid Sound is mostly restricted to that from studies conducted with limited spatial or temporal extents. In addition, many of the past data sets have been collected with different methodologies or with methodologies that suffer from inadequate designs in not allowing general extrapolation of data (Harvey et al. 2000). The most recent and longest temporal coral monitoring data sets for Dampier Harbour were collected in 2004 in conjunction with a previous dredging programme (Stoddart et al. 2005). Extended monitoring from the 2004 study and other more recent dredging programmes have added to the data set (MScience 2005b, 2006c).

Within many areas of the Harbour fringes, coral is extremely patchy in abundance and small spatial shifts in the alignment of measuring transects can result in major changes in estimates of abundance. Thus the use of consistent transects for historical continuity is important. It is therefore considered essential to build the baseline study and reactive monitoring sites around existing sites where possible, and use field techniques which allow for direct comparison to past data sets.

Methodology

The methodology for the baseline coral monitoring will follow Stoddart et al. (2005). The survey will include eight coral communities that will be used to evaluate rates of change in coral cover prior to dredge commencement.

Sets of 5x10 m transects with a width of approximately 50 cm will be established at each monitoring site. Sites will be surveyed on a monthly interval to allow discrimination of individual events likely to change coral abundance throughout the baseline study program.

Divers will be deployed to visually record the status of coral communities, noting the presence of excess sediments on corals, coral predators, mucus and the level of fish grazing scars at each site. This will be achieved by taking digital images along each transect. The images will then be scored using 25 points applied to each image in a stratified random design (Stoddart et al. 2005). Benthic cover intersected will be classified into the categories in **Table A2**.

The proposed methodology addresses the following criteria:

- The technique returns an approximate 10% level of precision in detecting relative change in coral cover; or about 2-5% in absolute terms for coral communities with 20 to 50% coral cover
- It has the capacity to underpin statistical tests of change in the cover of live coral.
- It allows evaluation of change in the common taxa of coral present which might be caused by selective mortality during elevated sediment levels.
- It provides a high definition image record able to be analysed in the future for other parameters, including taxonomy.
- It is repeatable, not heavily subject to observer bias, practical and able to be conducted rapidly to provide an operational tool for management.
- It is relevant to other studies of coral community composition and change over time and be capable of building into a long term data set to assist future relevant management within Dampier Port.

A.6 Location of Monitoring Sites

Juxtaposition of sediment and coral monitoring sites will allow comparison of any changes in the coral parameters with those which might be driving factors from the sedimentation. In selection of the sedimentation and coral monitoring sites the following parameters have been considered:

- Sites should be close to the nearest sensitive receptors (in this case high cover coral communities).
- Sites should be capable of providing a sentinel for detection of unacceptably high levels of sedimentation on the boundaries of the proposed marine parks.
- Sites should contain 'coral communities' which is arbitrarily defined as areas of over 50 m^2 with essentially contiguous cover of corals above 10% live coral cover.
- Coral monitoring sites should represent coral communities nearest to the impact sources and capable of representing communities with locally high ecological, biodiversity or social values.
- Sites should be located where possible to make use of any existing historic monitoring data collected with comparable methods.

The set of five sediment monitoring sites and eight coral monitoring sites are shown in **Figure A1** and described in **Table A3**. Preliminary models of sediment transport as presented in **Section 7.9.9** of the Draft PER have been used to evaluate the optimal number of monitoring sites for the purpose of collecting baseline data. The relationship of sites to modelled sediment dispersion and the rationale for choosing them is provided in **Table A3**.

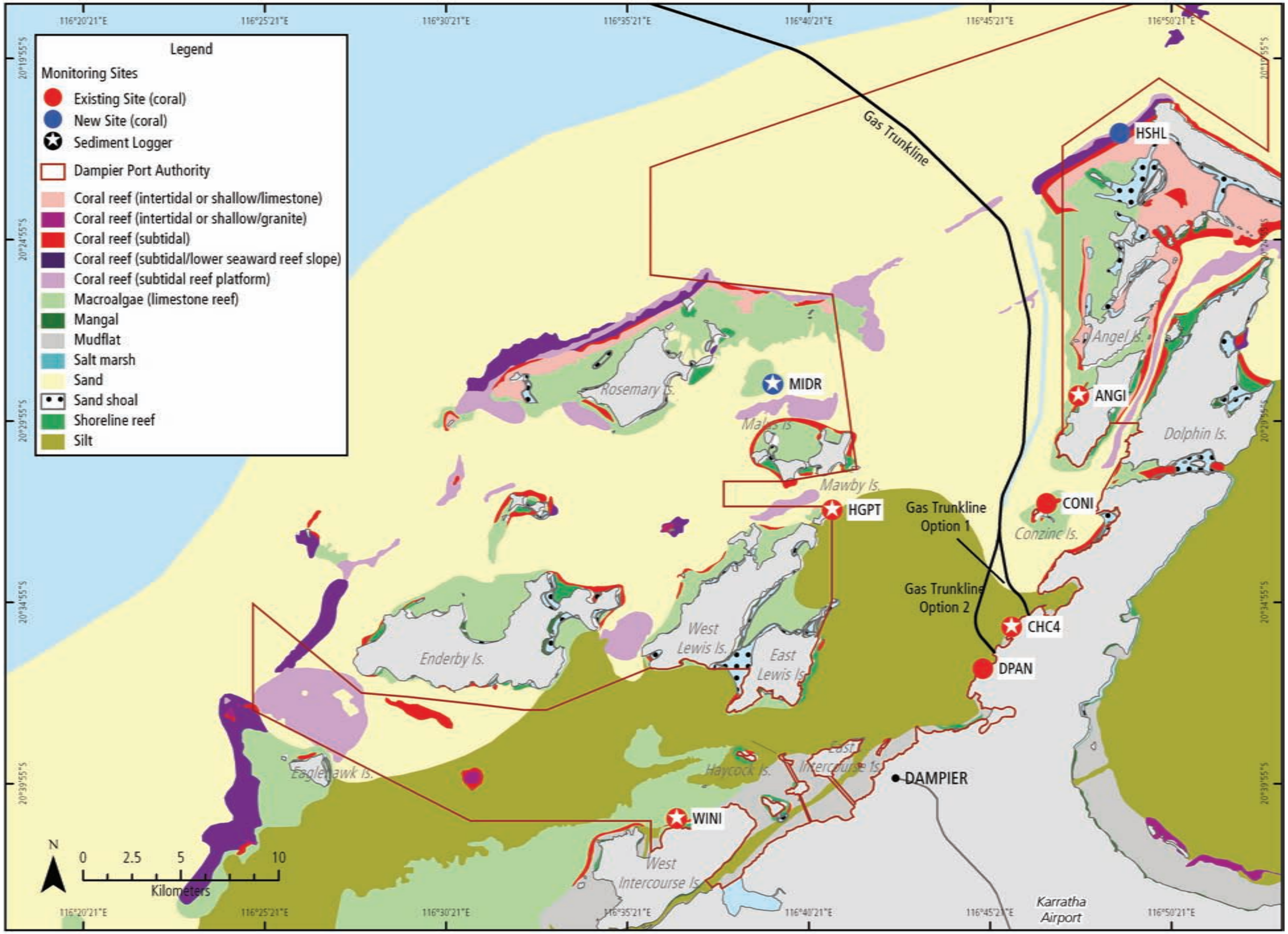
Table A2 Benthic Categories to be Scored in Transects

Category	Description
Live Coral	
Acropora	Members of the genus *Acropora*
Faviids	Members of the family *Faviidae* – a wide range of species with the most common *Goniastrea australensis* or *Platygyra sinensis*.
Pavona	Members of the genus *Pavona* – almost exclusively *Pavona decussata*
Porites	Members of the genus *Porites* - most commonly *Porites solida* and *Porites lobata*.
Turbinaria	Members of the genus *Turbinaria* – mostly comprising the 4 species commonly found in Mermaid Sound.
Other coral	All Scleractinian coral species not included above – plus Millporid corals.
Abiotic habitat	Rock, rubble, sand, including sparse turf algal cover.
Fauna	All benthic fauna other than Scleractinian coral: soft corals, urchins, zooanthids, sponges.
Flora	All floating or attached flora: macro-algae, sea grasses, dense turf algae.
Unknown	Items which are either part of the monitoring equipment (rope etc) or unable to be identified – these are excluded from future analysis.
Dead coral	Coral that retains the 'all white' appearance of recently dead coral – before being colonised by green algae: after that scored as rubble.

Table A3 Rationale for Selection of Baseline Study Sites

Site	Monitoring Parameter	Model Predictions	Rationale
WINI	Sediment Coral	N/A	This site has been used previously as an un-impacted reference, but is known to sustain high levels of wind derived sedimentation
DPAN	Coral	The model suggests significant sediment transport to the north and south of the uplift area	This site is the southern impact sentinel
CHC4	Sediment Coral	Model predictions show heavy sedimentation occurring in this area which is close to the uplift site	This site provides an indicator of potentially significant impacts and will aid in the establishment of LD50 thresholds
CONI	Coral	Model predictions show substantial sedimentation in this area	The monitoring site acts as an indicator for impacts coming into the marine park
HGPT	Sediment Coral	Model predictions suggest occasional sedimentation in this area from disposal sites A/B and Northern Extension of A/B	The area does not have a history of sedimentation from past projects and would provide an important sentinel for sediments entering the marine park
ANGI	Sediment Coral	Model predictions show high levels of sedimentation from the Northern Extension of Spoil Ground A/B entering this area	Area is known to contain sensitive corals
HSHL	Coral	Model predictions suggest that impacts here are unlikely	This is a significant habitat at the edge of the marine park and demonstration of nil impact will be of great importance. Also the base variability in this area is unknown at present
MIDR	Sediment Coral	Model predictions show frequent sediment ingress into this area from the offshore spoil disposal site 2B, though no losses are predicted	This area is a high value ecological asset at the edge of the marine park

Figure A1 Sedimentation and Coral Health Site Locations for the Baseline Study



Appendix B

Reactive Monitoring Programme

B.1 Scope of the Reactive Monitoring

The scope of the reactive monitoring programme is to implement monitoring of sufficient spatial and temporal extent to enable early detection of unacceptable sedimentation levels and/or declines in coral cover. Early detection will allow for timely implementation of management measures.

The trigger levels will be developed on the basis of the Baseline pre-dredge study (**Section 7.3.1** of the Draft PER and **Appendix A**).

Prior to commencement of the Pluto LNG Development dredging programme a detailed plan for the Reactive Coral Monitoring will be developed. This plan will specifically detail the design and timing of the coral and water quality monitoring to be implemented throughout the dredging programme, and will include the post-dredging impact monitoring.

B.2 Outline of the Reactive Monitoring Programme

B.2.1 Monitoring sites

For the purpose of both water quality and coral health monitoring two types of monitoring sites have been identified:

- Impact sites: Coral communities in close approximation to dredging or spoil disposal activities predicted to be affected by sedimentation, but with no associated loss of habitat
- Reference sites: Coral communities similar in species composition, live coral cover and physical settings as the impact sites, but outside predicted area of impact.

All sites will be placed, where possible, in areas of coral cover in excess of 20%, and preferably at sites where previous monitoring data is available, including data from the baseline study described in **Appendix A**.

The proposed 13 sites for the reactive monitoring within and outside Mermaid Sound are presented in **Figure B1** and described in **Table B1**. **Table B1** lists the sites proposed to be monitored for the entire duration of the dredging programme.

B.2.2 Methodology for Data Collection

Data on coral health and sedimentation rates will be collected using the same technique as for the baseline study (**Appendix A**). Data on coral health will be collected over a wider area than the baseline study, while sedimentation levels will be collected from the same number of sites, as shown in **Figure B1**. However, sediment loggers can be shifted from one location to another, subject to the development of the detailed dredging programme.

The coral health reactive monitoring is scheduled to commence approximately two weeks prior to the commencement of the dredging and disposal programme. This will ensure the establishment of basic data such as coral health, live coral cover and species composition at all of the monitoring sites, including the ones not surveyed during the baseline study. The timing and regularity of sampling will be outlined in the detailed DSDMP in agreement with the regulatory authorities

Appropriate statistical tests will be applied to the data collected during the Coral Health Monitoring Programme capable of detecting significant increases in gross coral mortality caused by dredging and spoil disposal activities.

B.2.3 Tiered Management System

Sedimentation trigger levels: Using data collected during the baseline study two sedimentation trigger levels (trigger level 1 and trigger level 2) will be developed to reflect the upper limits of the ambient environment in Mermaid Sound. Depending on the results, different trigger levels may need to be developed for the inner and outer harbour and for summer and winter conditions.

Coral health trigger levels: Trigger levels of acceptable decline in live coral cover will be established prior to the development of the detailed DSDMP in conjunction with the regulatory authorities. To avoid natural decline in coral cover being wrongly attributed to negative impacts from dredging, coral mortality will be simultaneously monitored at impact and reference sites, as outlined in **Section B.2.1**. This allows the net mortality on impact sites to be estimated as:

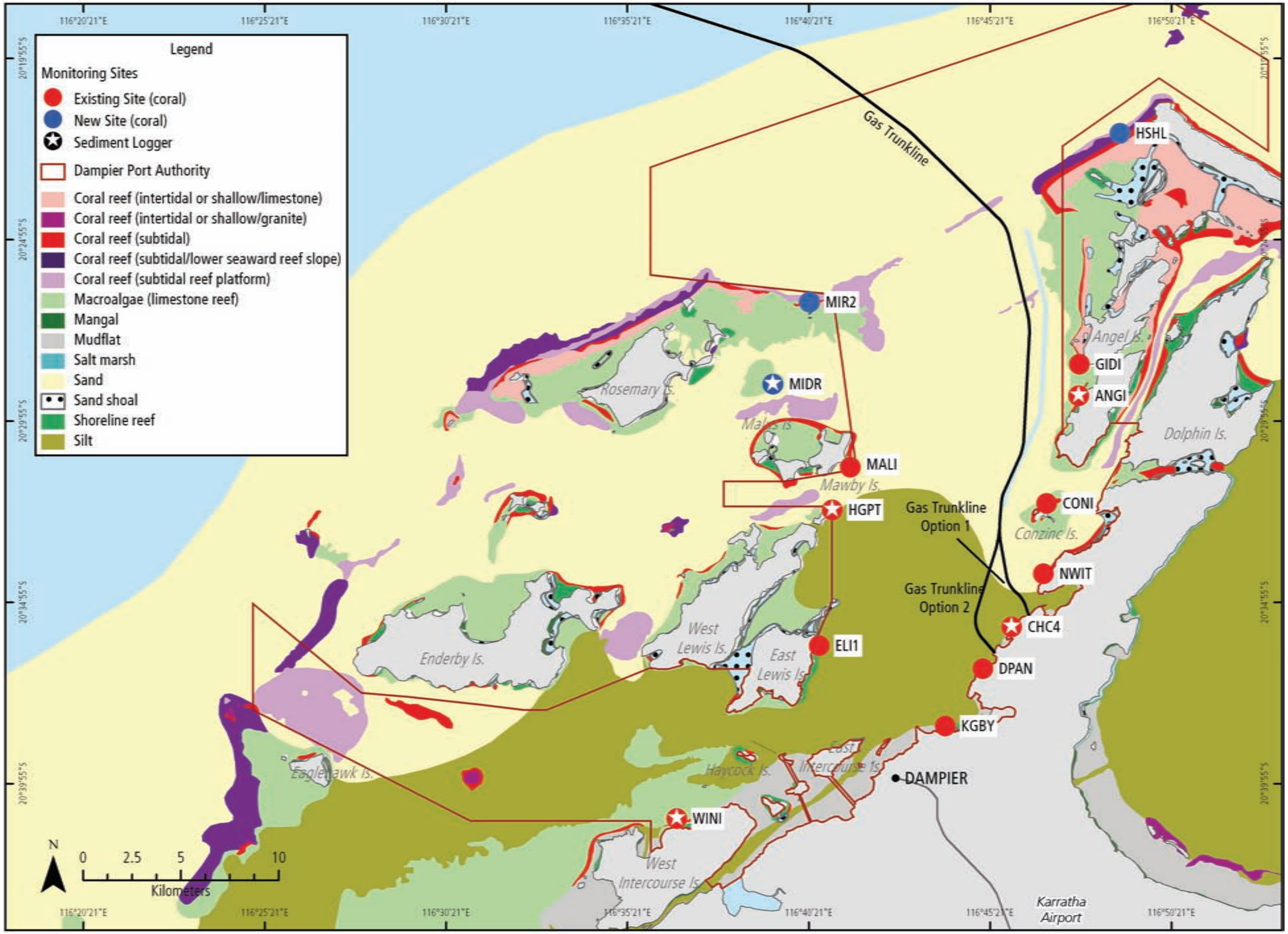
Net mortality = total mortality at impact site – total mortality at reference site

To be comparable these two measures of mortality must originate from the same time period and from impact site and appropriate reference site with similar coral community and conditions.

Table B1 Monitoring Sites for the Reactive Monitoring

Site ID	Type of Site	Approximate Duration of Exposure	Monitoring Programme
KGBY	Impact	24	Reactive (coral) Post dredging (coral)
DPAN	Impact	24	Baseline (coral) Post dredging (coral)
CHC4	Impact	24	Baseline (coral + sediment) Reactive (coral + sediment) Post dredging (coral)
NWIT	Impact	24	Reactive coral Post baseline coral
CONI	Impact	8	Baseline (coral + sediment) Reactive (coral + sediment) Post dredging (coral)
ANGI	Impact	8	Baseline (coral + sediment) Reactive (coral + sediment) Post dredging (coral)
MIDR	Impact	20	Baseline (coral + sediment) Reactive (coral + sediment) Post dredging (coral)
MIR2	Impact	20	Baseline (coral) Reactive (coral) Post dredging (coral)
GIDI	Reference	-	Reactive (coral) Post dredging (coral)
HSHL	Reference	-	Baseline (coral) Reactive (coral) Post dredging (coral)
MALI	Reference	-	Reactive (coral) Post dredging (coral)
HGPT	Reference	-	Baseline (coral) Reactive (coral) Post dredging (coral)
ELI1	Reference	-	Reactive (coral) Post dredging (coral)

Figure B1 Sedimentation and Coral Health Sites for the Reactive Monitoring Programme



Framework Marine and Intertidal Monitoring Programme

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The following is a framework monitoring programme for the marine and intertidal components of the Pluto LNG Development. The purpose of the framework is to outline the principles and key components of the ecological monitoring programme. It is recognised that additional information regarding biological and physical parameters will continue to be obtained throughout the life of the project and that stakeholder concerns, including regulatory bodies, may well alter as newer information is gained.

Woodside's over-riding goal is to plan and perform activities so that impact on the environment is either avoided or minimised to as low as reasonably practicable. A functional aspect of achieving this goal is to have a monitoring programme to measure changes in environmental characteristics attributable to the Pluto LNG Development. Data collected in the monitoring programmes will:

- enable reporting to stakeholders (including regulatory agencies) on environmental performance
- allow differences between predicted and actual impacts to be quantified and the need for additional environmental management identified
- ultimately ensure that no significant adverse environmental impacts occur.

The monitoring programme will be developed in consultation with key stakeholders, including regulatory authorities, and will be reviewed and updated as the project progresses. Input from stakeholders, including NWSV, Pilbara Iron, the Department of Environment and Conservation will be considered during the development of the monitoring programme. An important goal for the marine and intertidal components of the Pluto LNG Development is to achieve effective monitoring programmes and use of resources through opportunities to work in synergy with other regional marine monitoring initiatives, such as monitoring programmes that are progressed by the Dampier Port Authority and by other government agencies, for example in relation to marine conservation and protection areas, such as the Dampier Archipelago Marine Park.

The framework monitoring programme design is based on current best practice, including applicable standards and guidelines, results from baseline environmental surveys, expectations and requirements of regulatory authorities, commitments in the Draft PER and experience gained on similar projects.

The data gathered during specific surveys are used in the description of the project area for the Draft PER (particularly the aspects which were poorly known prior to undertaking these baseline surveys) and to place project area into a regional, national and international context. They also provide data which can be used to design ongoing monitoring programmes, including data for use in a pilot study and for statistical power analyses.

A number of surveys and studies have either already been undertaken or are underway for the Pluto LNG Development. They include:

- geotechnical and seabed surveys
- metocean measurements and hydrodynamic modelling
- offshore environmental and underwater noise surveys
- nearshore survey of turtle activity
- coral and background sediment baseline study.

These studies and surveys cover sites in the immediate project area (field, platform, export trunkline, near shore facilities, beach crossing and LNG processing facilities) and monitoring sites in Mermaid Sound.

Baseline studies involved the collection of a broad range of parameters, based on a combination of 'best of practice', parameters used to assess impacts from other similar developments and parameters targeted at detecting the predicted impacts of the Development. Monitoring parameters will be selected, with the assistance of further baseline surveys where necessary, before construction commences. The assessment parameters below are given as examples and not necessarily the ones that will be included in monitoring programs. Final selection of parameters to be monitored will be chosen after a review of the results of all baseline studies and advice and agreement of the relevant regulatory authorities.

1.1 Monitoring Parameters

The assessment parameters are expected to include:

- epifauna community diversity and abundance, including coral monitoring (refer to Framework Dredging and Spoil Disposal Management Plan, **Appendix I**)
- turtle abundance and turtle nesting activity
- sediment quality – for example metals, particle size distribution, hydrocarbons and organics
- water quality – for example standard physio-chemical parameters (for example, pH, salinity, DO, turbidity, and temperature), hydrocarbons, organics and metals
- treated waste water ecotoxicological assessment.

1.2 Monitoring Locations

The Pluto LNG Development covers a wide geographical area and a range of marine habitats, from intertidal areas to the deeper offshore water and seafloor. The monitoring programmes will target the main environmental sensitivities of the different habitats potentially affected by the Pluto LNG Development. Locations to be monitored include:

- the offshore drill site(s)
- the offshore platform site
- selected sections of trunkline route and shore crossings
- the export jetty
- dredging and spoil disposal grounds
- operational discharge points
- locations in Mermaid Sound that are part of marine monitoring programmes.

1.2.1 Offshore

1.2.1.1 Pluto Gas Field and Platform

Drill site monitoring will focus on the location of the wells on the continental slope and the platform monitoring will focus on the platform location on the continental shelf. The effect of drilling discharges on benthic epifuana and demersal fauna communities was monitored during drilling of the Pluto-2 appraisal well. Further monitoring, using appropriate methods to ensure consistency and allow inter-comparison of results, will be conducted during the drilling of production wells at the Pluto gas field location.

1.2.1.2 Treated Waste Water Discharges

The treated waste water monitoring programme is described in **Table G-3**, **Appendix G**.

Treated waste water will be monitored for:

- faecal coliforms
- Biological Oxygen Demand (BODs)
- chemical oxygen demand
- total suspended solids
- concentration of MEG in water
- total dissolved hydrocarbon
- total petroleum hydrocarbons
- total suspended solids
- grease.

Ecological monitoring will be carried out at selected sites to confirm predictions made in relation to environmental impacts.

1.2.2 Nearshore

1.2.2.1 ChEMMS

Woodside has been monitoring the environment around the Karratha Gas Plant since 1985 when the Chemical and Ecological Monitoring of Mermaid Sound (ChEMMS) programme commenced. Since that time, semi-annual surveys have been conducted in November/December and April/July of each year, with the programme reviewed and amended, where appropriate, every three years. Relevant aspects of the programme comprise chemical and biological monitoring of the intertidal and subtidal environment adjacent to, and in the vicinity of, Woodside's port facilities in Mermaid Sound. The current programme investigates the concentration of metal and hydrocarbons in oyster and biological monitoring of mangroves, intertidal rocky shore biota and coral communities. The CheMMS programme will be an excellent long-term baseline and ongoing monitoring programme to measure nearshore impacts along the Burrup Peninsular attributable to the Pluto LNG Development, including the port facilities and any nearshore discharges.

1.2.2.2 Dredging

A Framework Dredging and Spoil Disposal Management Plan is outlined in Appendix I which outlines the monitoring which will be undertaken to minimise impacts associated with dredging activities. Parameters to be monitored include:

- coral health and habitat
- water quality.

Vegetation Association Descriptions

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Table 1 Vegetation associations identified by Trudgen (2002) for Site B

Code	Description
Hummock Grasslands, Hummock/Tussock Grasslands	
Te	*Triodia epactia* (Burrup form) hummock grassland.
TeEtSg	*Triodia epactia* (Burrup form), (*Cyperus Acacia*), *Eriachne tenuiculmis* hummock grassland / sedgeland with *Stemodia grossa* annual herbland.
TeCa	*Triodia epactia* (Burrup form), *Cymbopogon ambiguus* hummock/tussock grassland.
TeRm	*Triodia epactia* (Burrup form) hummock grassland with *Rhynchosia* cf. *minima* lianes.
Acacia bivenosa (with various other species) scattered shrubs to high shrublands	
AbCcTe	*Acacia bivenosa* scattered shrubs to tall scattered shrubs over *Cajanus cinereus*, *Indigofera monophylla* (Burrup form) low shrubland over *Triodia epactia* (Burrup form), *Cymbopogon ambiguus* hummock/tussock grassland to closed hummock/tussock grassland.
AbCwTe	*Acacia bivenosa* scattered tall shrubs to high open shrubland over *Indigofera monophylla* (Burrup form), *Corchorus walcottii* scattered low shrubs over *Triodia epactia* (Burrup form) hummock grassland.
Acacia colei (with various other species) scattered shrubs to high shrublands	
AcCaTe	*Acacia colei*, *Cullen pustulatum* high open shrubland over *Indigofera monophylla* (Burrup form), *Triumfetta appendiculata* (Burrup form) low shrubland with *Cymbopogon ambiguus*, *Triodia epactia* (Burrup form) tussock/hummock grassland.
AcImTe	*Acacia colei*, *Acacia elacantha* high open shrub land over *Grevillea pyramidalis* subsp. pyramidalis scattered shrubs over *Indigofera monophylla* (Burrup form) scattered low shrubs to low open shrubland over *Triodia epactia* (Burrup form), *Triodia wiseana* (Burrup form) hummock grassland.
AcImTe/TeCa	Mosaic: *Acacia colei*, *Acacia elacantha* high open shrub land over *Grevillea pyramidalis* subsp. *pyramidalis* scattered shrubs over *Indigofera monophylla* (Burrup form) scattered low shrubs to low open shrubland over *Triodia epactia* (Burrup form), *Triodia wiseana* (Burrup form) hummock grassland: *Triodia epactia* (Burrup form), *Cymbopogon ambiguus* hummock/tussock grassland.
AcImTh	*Acacia colei* shrubland over *Indigofera monophylla* (Burrup form) low open shrubland over *Themeda* sp Burrup (B84), *Triodia epactia* (Burrup form) tussock/hummock grassland.
Acaciainaequilatera (with various other species) scattered shrubs to high shrublands	
AiFdTe	*Acacia inaequilatera*, *Hakea chordophylla*, G*revilla pyramidalis* scattered shrubs to open shrubland over *Corchorus walcottii* scattered low shrubs over *Triodia epactia* (Burrup form) dense hummock grassland over *Fimbristylis* aff. *Dichotoma* (M75–4) low open sedgeland with *Rhynchosia* cf. *minima* low lianes.
AiTe	*Acacia inaequilatera*, *Acacia colei*, *Acacia bivenosa*, *Acacia coriacea* subsp *coriacea*, *Acacia pyrifolia* (slender white) *Acacia elacantha* shrubland over *Triodia epactia* (Burrup form) hummock grassland.
Indigofera monophylla (Burrup form) scattered low open shrubs to shrubland	
ImTeAc	*Indigofera monophylla* (Burrup form) scattered shrubs to low open heath over *Triodia epactia* (Burrup form) hummock grassland to closed hummock grassland.
Corymbia hamersleyana scattered low trees to low woodlands	
ChAcTe	*Corymbia hamersleyana* scattered low trees to low open woodland over *Acacia colei*, *Grevillea pyramidalis* subsp. *pyramidalis* scattered tall shrubs to high open shrubland over *Indigofera monophylla* (Burrup form) scattered low shrubs to low open shrubland over *Triodia epactia* (Burrup form), (*Triodia wiseana* (Burrup form)) hummock grassland.
ChTh	*Corymbia hamersleyana* scattered low trees to low woodland over *Acacia bivenosa*, *Acacia colei* scattered tall shrubs to low open shrubland over *Indigofera monophylla* (Burrup form) over *Triodia epactia* (Burrup form), *Themeda* sp. Burrup (B84) hummock/tussock grassland.
Shrublands and high shrublands of Cullen pustulatum, Cajanus cinereus and various other species	
CpTe	*Cullen pustulatum* scattered tall shrubs over *Triodia epactia* (Burrup form) hummock grassland.
Eucalyptus vitrix scattered low trees, low open woodlands and low woodlands	
EvTr	Scattered trees of *Eucalyptus victrix* over *Tephrosia rosea* var. *clementii* low open shrubland over *Triodia epactia* (Burrup form) *Triodia angusta* (Burrup form) hummock grassland.
EvTa	*Eucalyptus victrix* low open woodland to low woodland over *Acacia coriacea* subsp. *Coriacea* scattered tall shrubs over *Triodia angusta* (Burrup form) hummock grassland.
Eucalyptus vitrix, Terminalia canescens low open woodlands to low open forests	
EvTaCv	*Eucalyptus victrix* (*Terminalia canescens*) low woodland to low open forest over *Acacia coriacea* subsp. coriacea scattered tall shrubs over *Triodia angusta* (Burrup form), *Triodia epactia* (Burrup form), *Cyperus vaginatus*, (*Cyperus bifax*) hummock grassland/ sedgeland with *Sesbania cannabina* scattered herbs to open herbland and *Stemodia grossa*, (*Dicliptera armata*) low annual herbland.

Terminalia canescens scattered low trees to low woodland with Corymbia hamersleyana, Brachychiton acuminatus or Eucalyptus victrix	
TcCvSe	Scattered low trees of *Terminalia canescens*, *Brachychiton acuminatus* over *Cyperus vaginatus* open sedgeland with *Sesbania canabina* annual tall herbland.
Terminalia canescens scattered low trees to low forest	
TcDsDa	*Terminalia canescens* low open woodland to low closed forest over (*Dichrostachys spicata*, *Flueggea virosa* subsp. *melanthesoides*) high open shrubland to shrubland over *Dicliptera armata* annual herbland.
TcSg	*Terminalia canescens* scattered low trees to low open forest over *Cyperus vaginatus*, *Triodia angusta* (Burrup form) sedgeland/ hummock grassland with *Stemodia gross*a low herbland to open herbland.
*Indigofera monophylla (Burrup form) scattered low open shrubs to shrubland*d	
ImTrTe	*Indigofera monophylla* (Burrup form), *Tephrosea rosea* var. *clementii* low shrubland over *Triodia epactia* (Burrup form) (*Triodia angusta* Burrup form) hummock grassland.

Table 2 Vegetation associations identified by Trudgen (2002) for Site A

Code	Description
Hummock Grasslands, Hummock/Tussock Grasslands	
TeAb	*Triodia epactia* (Burrup form) hummock grassland with scattered *Acacia bivenosa*.
Te	*Triodia epactia* (Burrup form) hummock grassland.
TeCa	*Triodia epactia* (Burrup form), *Cymbopogon ambiguus* hummock/tussock grassland.
TeRm	*Triodia epactia* (Burrup form) hummock grassland with *Rhynchosia cf. minimalianes*.
Tussock Grasslands and Tussock/Hummock Grasslands	
Sv	*Sporobolus virginicus* tussock grassland.
Samphires	
Sm	*Halosarcia* spp. scattered low shrubs to low open heath.
Herblands	
SgTeTa	*Stemodia grossa* low open shrubland to open scrub over *Triodia epactia* (Burrup form), *Triodia angusta* (Burrup form) hummock grassland to closed hummock grassland
Acacia colei (with various other species) scattered shrubs to high shrublands	
AcImTe	*Acacia colei, Acacia elacantha* high open shrub land over *Grevillea pyramidalis* subsp. *pyramidalis* scattered shrubs over *Indigofera monophylla* (Burrup form) scattered low shrubs to low open shrubland over *Triodia epactia* (Burrup form), *Triodia wiseana* (Burrup form) hummock grassland
Ac'Te	*Acacia colei, Acacia inaequilatera, Hakea lorea* subsp. lorea, *Grevillea pyramidalis* subsp. *pyramidalis, Acacia bivenosa* shrubland over *Triodia epactia* (Burrup form), (*Triodia angusta* (Burrup form)) closed hummock grassland.
Acacia bivenosa (with various other species) scattered shrubs to high shrublands	
AbTe	*Acacia bivenosa* scattered tall shrubs to high shrubland over *Triodia epactia* (Burrup form) hummock grassland.
Terminalia supranitifolia with various other species, open shrublands to high shrublands or open scrub, sometimes low open woodland.	
Ts'Ac'Te	*Terminalia supranitifolia, Acacia coriacea* subsp. *coriacea, Stylobasium spathulatum* shrub land (high shrubland) over *Cyperus vaginatus, Triodia epactia* (Burrup form) sedgeland/grassland with *Rhynchosia* sp. Burrup (82–1 C) low vineland.
Low open shrublands to low open heath dominated by various species	
CwTe	*Corchorus walcottii* low open shrubland to low shrub land over *Triodia epactia* (Burrup form) hummock grassland to closed hummock grassland.
ItTa	*Indigofera trita* low shrubland over *Triodia angusta* (Burrup form), *Triodia epactia* (Burrup form) hummock grassland
Indigofera monophylla (Burrup form) scattered low open shrubs to shrubland	
ImTeAc	*Indigofera monophylla* (Burrup form) scattered shrubs to low open heath over *Triodia epactia* (Burrup form) hummock grassland to closed hummock grassland.
Acacia coriacae subsp. coriacae scattered low shrubs to tall shrublands	
GpImTe	*Grevillea pyramidalis* subsp. *pyramidalis, Acacia colei* open shrubland over *Indigofera monophylla* (Burrup form) low open shrub land over *Triodia epactia* (Burrup form) hummock grassland.
Brachychiton acuminatus scattered low trees to low open woodland with various other low tree species	
BaTcTe	*Brachychiton acuminatus, Terminalia canescens* scattered trees over *Flueggea virosa* subsp. *melanthesoides* tall open shrubland over *Indigofera monophylla* (Burrup form) scattered low shrubs over *Triodia epactia* (Burrup form) hummock grassland.
Adriana tomentosa scattered low open shrubs to heath	
AtSl	*Adriana tomentosa* (*Corchorus walcottii*) scattered low shrubs over *Spinifex longifolius, Triodia epactia* (Burrup form) open hummock grassland.
Eucalyptus victrix, Terminalia canescens low open woodlands to low open forest	
EvTaCv	*Eucalyptus victrix* (*Terminalia canescens*) low woodland to low open forest over *Acacia coriacea* subsp. *coriacea* scattered tall shrubs over Triodia angusta (Burrup form), *Triodia epactia* (Burrup form), *Cyperus vaginatus*, (*Cyperus bifax*) hummock grassland/sedgeland with *Sesbania cannabina* scattered herbs to open herbland and *Stemodia grossa*, (*Dicliptera armata*) low annual herbland.

Shrublands and high shrublands of Cullen pustulatum, Cajanus cinereus and various other species	
DsTsTe	*Dichrostachys spicata* open shrubland over *Tephrosia aff supina* (MET 12,357), *Indigofera monophylla* (Burrup form), *Triumfetta appendiculata* (Burrup form) low open heath over *Triodia epactia* (Burrup form), *Triodia angusta* (Burrup form) hummock grassland.
Ipomoea costata scattered shrubs to shrublands	
IcImTe	*Ipomoea costata* open shrubland to shrubland over *Indigofera monophylla* (Burrup form) low shrubland over *Triodia epactia* (Burrup form) hummock grassland.
Other Habitats	
MF	Mudflat
R	Rock piles
RC	Rocky coast
S	Sand

Table 3 Vegetation associations identified by Astron (2006) for Site B South

Code	Description
Rockpiles, Ridges and Outcrops and Gully Walls	
TcFvAc	Low woodland (10–30% <10 m) of *Terminalia canescens* with *Flueggea virosa* subsp. *melanthesoides, Clerodendrum tomentose, Brachychiton acuminatus* over open (2–10% 2 m) shrubland of *Acacia coriacea, Rhagodia preissii* sub sp. *preissii* over scattered (<2%) *Cymbopogon ambiguus.* There is annual herbland of *Dicliptera armata.*
BaTsFv	Pocket vegetation. Low woodland (10–30% <10 m) of *Brachychiton acuminatus, Terminalia supranitifolia, Flueggea virosa* subsp. *melanthesoides* with *Ficus brachypoda, Ipomoea costata, Ehretia saligna* over scattered (<2%) *Cymbopogon ambiguus.*
TcBaTeCa	Low mixed woodland (10–30% <10 m) of *Terminalia canescens, Brachychiton acuminatus* with *Terminalia supranitifolia, Ficus brachypoda, Clerodendrum tomentosum* over fingers of hummock grassland of *Triodia epactia* (Burrup form), *Cymbopogon ambiguus.*
Drainage Lines and Gullies	
TcFvCv	Low woodland to open forest (20–50% <10 m) of *Terminalia canescens* with *Flueggea virosa* subsp. *melanthesoides* and *Brachychiton acuminatus* over low open shrubland (2–10% 1–2 m) of *Acacia coriacea* over open *Cymbopogon ambiguusgrass* and *Cyperus vaginatuss* edges and annual herbs of *Dicliptera armata, Abutilon fraseri.*
ChSgTa	Low woodland (10–30% <10 m) of *Corymbia hamersleyana* over dwarf shrubland (10–30% <0.5 m) of *Stemodia grossa* and *Pluchea rubelliflora* over open (10–30%) hummock grassland of *Triodia angusta* (Burrup form) with *T. epactia* (Burrup form) with open sedgeland (2–10%) of *Cyperus vaginatus.*
CpTaCv	Open high shrubland (2–10% >2 m) of *Cullen pustulatum* over open dwarf shrubland (2–10% <0.5 m) of *Triumfetta appendiculata, Corchorus walcottiiover* sedgeland (10–30%) of *Cyperus vaginatus* with open (2–10%) hummock grass of *Triodia epactia* (Burrup form).
EvSgTaCv	Low woodland (10–30% <10 m) of *Eucalyptus victrix* over open shrubland (2–10% 1–2 m) of *Acacia coriacea* over dwarf shrubland (10–30% <0.5 m) of *Stemodia grossa* sometimes *Tephrosia rosea* over open hummock grassland (10–30%) *Triodia epactia* (Burrup form) and sedges of *Cyperus vaginatus* over herbs.
EvSgTa	Low woodland (10–30% <10 m) of *Eucalyptus victrix* over very open dwarf (2–10% <0.5 m) shrubland of *Stemodia grossa* and *Triumfetta appendiculata* over hummock grassland of *Triodia angusta* (Burrup form).
ChCwTe	Open low woodland (2–10% <10 m) of *Corymbia hamersleyana* over open dwarf shrubland (2–10% <0.5 m) of *Corchorus walcottii* and *Indigofera monophylla* over open hummock grassland of *Triodia epactia* (Burrup form) with occasional *Cymbopogon ambiguus.*
TcSgCaTa	Low woodland (10–30% <10 m) of *Terminalia canescens* over open dwarf shrubland (2–10% <0.5 m) of *Stemodia grossa* mixed open grassland of *Cymbopogon ambiguus* with *Triodia epactia* (Burrup form) and open sedgeland of *Cyperus vaginatus.*
SgTeEt	Dwarf open shrubland (2–10% <0.5 m) of *Stemodia grossa* over open (10–30%) hummock grassland of *Triodia epactia* (Burrup form) and occasional *Eriachne tenuiculmis.*
SgTaCv	Low open heath (30–70% <1 m) of *Stemodia grossa* over hummock grassland of *Triodia angusta* (Burrup form) and sedgeland of *Cyperus vaginatus.*
Upper Undulating Hillslopes and Plateau	
ImTe	Open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* over hummock grassland (30–70%) of *Triodia epactia* (Burrup form). There are scattered (<2%) shrubs of *Acacia bivenosa, Dichrostachys spicata, Cullen pustulatum* and trees of *Corymbia hamersleyana.*
ChImTe	Scattered to very open low woodland (2–10% <10 m) of *Corymbia hamersleyana* over open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* over hummock grassland of *Triodia epactia* (Burrup form).
AbImTe (TsFvIp)	Open high shrubland (2–10% >2 m) of *Acacia bivenosa* over open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* (Burrup form) and *Corchorus walcottii* over hummock grassland of *Triodia epactia* (Burrup form) over herbland. There are sometimes scattered trees (<2%) of *Corymbia hamersleyana.* (Note: in this habitat are frequent small rockpiles with rockpile woodland – *Terminalia supranitifolia, Flueggea virosa subsp melanthesoides, Ipomoea costata*).
HlCpImTeCa	Mixed shrubland (10–30% 1–2 m) of *Hakea lorea* subsp *lorea Cullen pustulatum, Acacia bivenosa, Grevillea pyramidalis* and occasional *Acacia colei* over open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* (sometimes with *Corchorus walcottii, Hibiscus sturtii*) over mixed hummock *Triodia epacta* (Burrup form) and *Cymbopogon ambiguus* grassland with tall annual herbland of *Trachymene oleracea.* There are scattered (<2%) *Corymbia hamersleyana.*
TeCa	Mixed hummock *Triodia epactia* (Burrup form) and tussock *Cymbopogon ambiguus* grassland with tall annual herbland of *Trachymene oleracea.* There are scattered (<2%) *Acacia bivenosa, Acacia colei, Grevillea pyramidalis* subps *pyramidalis.*

CwTe	Dwarf shrubland (10–30% <0.5 m) of *Corchorus walcottii* over hummock grassland of *Triodia epactia* (Burrup form) with tall annual herbland of *Trachymene oleracea*.
CwImTrTe	Dwarf shrubland (10–30% (0.5 m) of *Corchorus walcottii, Indigofera monophylla* (Burrup form) *Tephrosia rosea* var. *clementi*, over hummock grassland of *Triodia epactia* (Burrup form).
TsBaGpTe	Open low woodland (2–10% <5 m) of *Terminalia supranitifolia*, *Brachychiton acuminatus*, *Ehretia saligna* on numerous small rockpiles surrounded by open shrubland (2–10% 1–2 m) of *Grevillea pyramidalis* subsp *pyramidalis*, *Hakea lorea* subsp *lorea*, *Acacia bivenosa* over open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla*, *Tephrosia rosea var clementii*, over hummock grassland of *Triodia epactia* (Burrup form) and annual herbland of *Trachymene oleracea*.
ImTeCa	Very open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* over mixed tussock and hummock grassland of *Cymbopogon ambiguus*, *Triodia epactia* (Burrup form). There are scattered *Cullen pustulatum, Acacia bivenosa*.
ImTeTh	Open dwarf shrubland (2–10% <0.5 m) of *Indigofera monophylla* (Burrup form) over hummock grassland of *Triodia epactia* (Burrup form) and tussock grass *Themeda triandra* (Burrup form). There are scattered *Grevillea pyramidalis* subsp. *pyramidalis, Acacia bivenosa, Acacia colei*.
AiAbTe	Open high shrubland (2–10% 2 m) of *Acacia inaequilatera*, *Acacia bivenosa* and *Acacia coriacea* subsp *coriacea*, over hummock grassland of *Triodia epactia* (Burrup form).
TcChGpTe	Scattered to open low woodland (2–10% <10 m) of *Terminalia canescens*, *Corymbia hamersleyana*, *Eucalyptus victrix* over tall open shrubland (2–10% 2 m) of *Grevillea pyramidalis* subsp *pyramidalis* with *Acacia bivenosa*, *Hakea lorea* subsp l*oreaover* hummock grassland of *Triodia epactia* (Burrup form) over tall annual herbland of *Trachymene oleracea*.
Low Rounded Hill Crests	
ChTeTh	Low woodland (10–30% <10 m) of *Corymbia hamersleyana* over open high shrubland (2–10% 2 m) of *Acacia bivenosa* over hummock grassland of *Triodia epactia* (Burrup form) and tussock grass of *Themeda triandra* (Burrup form) over herbland.
Rocky Hillslope Terraces	
TcBaTeCa	Open low woodland (2–10% <5 m) of T*erminalia canescens* with *Brachychiton acuminatus*, *Ipomoea costata* on rockpiles surrounded by hummock grassland of *Triodia epactia* (Burrup form) and tussock grassland of *Cymbopogon ambiguus* and dense annual herbland of *Trachymene oleracea.* There are scattered (<2%) *Grevillea pyramidalis.*

Table 4 Vegetation associations identified by Astron (2006) for Site B North

Code	Description
Rockpiles	
BaTcAcPtTe	Scattered low trees to low open woodland of *Brachychiton acuminatus, Terminalia canescens, Ipomoea costata, Dichrostachys spicata, Ficus brachypoda, Ehretia saligna var. saligna* over open shrubland of *Acacia coriacea* subsp. *coriacea, Flueggea virosa* subsp. *melanthesoides, Grevillea pyramidalis* subsp. *leucadendron* over open tussock / hummock grassland of *Paspalidium tabulatum* (Burrup Form), *Triodia epactia* (Burrup Form).
Major Drainage Line (A) – Low Woodland of Eucalyptus victrix and Terminalia canescens	
EvTcBaRmPtTa	Low woodland of *Eucalyptus victrix, Terminalia canescens* over high open shrubland of *Brachychiton acuminatus, Flueggea virosa* subsp. *melanthesoides, Acacia coriacea* subsp. *coriacea* over low open shrubland of *Rhynchosia minima* var. *australis* over open herbs (*Sesbania cannabina*), low annual herbland (*Dicliptera armata)* and very open sedgeland (*Cyperus vaginatus, Cyperus bifax*) over open grassland of *Paspalidium tabulatum* (Burrup Form) and very open hummock grassland of *Triodia angusta* (Burrup Form).
Major Drainage Line (B) – Low Woodland of Terminalia canescens	
TcBaRmPtTa	Low woodland of *Terminalia canescens* over high open shrubland of *Brachychiton acuminatus*, *Flueggea virosa* subsp. *melanthesoides*, *Dichrostachys spicata*, *Acacia coriacea* subsp. *coriacea* over low open shrubland of *Rhynchosia minima* var. australis, *Triumfetta appendiculata* (Burrup Form) over very open tussock / hummock grassland of *Paspalidium tabulatum* (Burrup Form) / *Triodia angusta* (Burrup Form) over open sedgeland (*Cyperus bifax*) and low annual herbland (*Dicliptera armata, Stemodia grossa*).
Drainage Line Minor	
TcRmTe	*Terminalia canescens, Flueggea virosa* subsp. *melanthesoides* low open woodland over *Rhynchosia minima* var. australis, *Indigofera monophylla* (Burrup Form), *Phyllanthus maderaspatensis, Triumfetta appendiculata* (Burrup Form), *Corchorus tridens* low open shrubland over *Triodia epactia* (Burrup Form) / *Eriachne tenuiculmis, Paspalidium tabulatum* (Burrup Form) open hummock / tussock grassland over *Dicliptera armata, Stemodia grossa* open herbfield.
Crest Above Drainage Line	
TcTe	High open shrubland of *Terminalia canescens, Ipomoea costata, Dichrostachys spicata, Brachychiton acuminatus* over mixed low open shrubland over *Triodia epactia* (Burrup Form) hummock grassland.
Upland Swales	
ChGpGsTe	Scattered low trees of *Corymbia hamersleyana* over scattered shrubs of *Grevillea pyramidalis* subsp. *leucadendron, Ipomoea costata, Dichrostachys spicata* over low open shrubland of *Goodenia stobbsiana, Hybanthus aurantiacus, Triumfetta appendiculata* (Burrup Form), *Triumfetta clementii, Triumfetta maconochieana, Indigofera monophylla (*Burrup form), *Abutilon lepidum* over hummock grassland *Triodia epactia* (Burrup Form).
Upland Stony Plateau	
GpAeTe	Scattered shrubs of *Grevillea pyramidalis* subsp. *leucadendron* over mixed low open shrubland (including *Acacia elachantha, Indigofera monophylla* (Burrup form), *Triumfetta clementii, Triumfetta maconochieana, Trachymene* aff. *oleracea, Hibiscus* aff. *platychlamys*) over open hummock grassland *Triodia epactia* (Burrup Form).
Gentle Slopes Adjacent to Rockpiles	
TaTe	Low open shrubland of *Triumfetta appendiculata* (Burrup Form), *Triumfetta clementii, Corchorus walcottii* over open hummock grassland of *Triodia epactia* (Burrup Form).

Table 5 Vegetation associations identified by Astron (2006) for Site A

Code	Description
Rocky Hill Slopes and Undulating Slopes	
TeCa	Mixed hummock *Triodia epactia* (Burrup form) and tussock *Cymbopogon ambiguus* grassland (30–70%) over annual herbland of *Trachymene oleracea, Trichodesma zeylanicum.* There are scattered low trees and shrubs associated with frequent small rockpiles.
AbTe	Tall shrubland (10–30% 2 m) of *Acacia bivenosa* with occasional *Hakea lorea* subsp *lorea, Cullen pustulatum* over hummock grassland of *Triodia epactia* (Burrup form). Very scattered occurrences of *Acacia inaequilatera.*
CpGpTe(TsBa)	Mixed open tall shrubland (2–10% 2 m) to tall shrubland (10–30% 2 m) of *Cullen pustulatum* with *Grevillea pryamidalis* subsp. *pyramidalis, Hakea lorea* subps. *lorea,* I*pomoea costata* over open dwarf (2–10% <0.5 m) shrubland of *Corchorus walcottii* over hummock grassland of *Triodia epactia* (Burrup form) and patches of *Cymbopogon ambiguus* and *T. wiseana.* Small rockpiles have frequent *Terminalia supranitifolia, Brachychiton acuminatus.*
AoAbTe	Open shrubland (2–10% 1–2 m) of *Acacia orthocarpa* and *Acacia bivenosa* over open dwarf shrubland (2–5% <0.5 m) of T*riumfetta appendiculata* (Burrup Form), *Corchorus walcotti*i over hummock grassland of *Triodia epactia* (Burrup form) with dense annual herbland.
Te(TapTs)	Hummock grassland (30–70%) of *Triodia epactia* (Burrup form) over tall annual herbland (10–30%) of *Trichodesma zeylanicum* var. *zeylanicum.*Scattered *Triumfetta appendiculata* (Burrup Form) and *Terminalia supranitifolia* (P1) on low rockpiles. There are sometimes scattered *Grevillea pyramidalis* subsp. *pyramidalis* and *Hakea lorea.*
AbAcCwTe	Mixed shrubland (10–30%; 1–2 m) of *Acacia bivenosa* with *Acacia coriacea, Ipomoea costata*, and *Stylobasium spathulatum* over dwarf shrubland (10–30%; <0.5 m) of *Corchorus walcottii* over hummock grassland of *Triodia epactia.*
TapTe(Ch)	Low open heath of *Triumfetta appendiculata* (Burrup Form) over hummock grassland (30–70%) of *Triodia epactia* (Burrup form) over tall annual herbland (10–30%) of *Trichodesma zeylanicum* var. *zeylanicum.* Scattered *Corymbia hamersleyana* and *Acacia colei.*
ImTeCa	Open dwarf shrubland (2–10%) of *Indigofera monophylla* (Burrup form) with occasional *Corchorus walcottii* over mixed grassland (30–70%) of *Triodia epactia* (Burrup form) and *Cymbopogon ambiguous.* Sometimes with scattered *Grevillea pyramidalis* subsp. *pyramidalis* and *Ipomoea pescaprae.*
AbHlImTe	Tall shrubland (10–30%; 2 m) of *Acacia bivenosa, Hakea lorea, Cullen pustulatum* over dwarf shrubland of *Indigofera monophylla* (Burrup form) (10–30% <0.5 m) with occasional *Acacia colei* over hummock grassland of *Triodia epactia* (Burrup form).
Drainage Lines and Rocky Gullies	
TapTeCa	Dwarf shrubland (10–30%; <0.5 m) of *Triumfetta appendiculata* (Burrup Form) with occasional *Stemodia grossa* over mixed grassland of *Triodia epactia* (Burrup form) with *Cymbopogon ambiguus* and sometimes *Eriachne tenuiculmis.*
EvTaCv	Low woodland (10–30%; <10 m) of *Eucalyptus victrixover* hummock grassland of *Triodia angusta* (Burrup form) with open herbland of *Pluchea rubelliflora* and sedges *Cyperus vaginatus.*
SgTapTa	Mixed open shrubland (2–10%; 1–2 m) of *Ipomoea costata, Acacia bivenosa, Cullen pustulatum* over dwarf shrubland (10–30%; <0.5 m) of *Stemodia grossa* and *Triumfetta appendiculata* (Burrup Form) over open (10–30%) hummock grassland of *Triodia angusta* (Burrup form), occasional *Triodia epactia* (Burrup form).
IcTapCaTa	Open shrubland (2–10%; 1–2 m) of *Ipomoea costata* over open mixed dwarf shrubland (2–10%; <0.5 m) of *Triumfetta appendiculata* (Burrup Form) and *Stemodia grossa* over mixed tussock and hummock grasslands of *Cymbopogon ambiguus* and *Triodia angusta* (Burrup form).
SsTapSgTa	Open heath (30–70%; 1–2 m) of *Stylobasium spathulatum* and *Acacia bivenosa* with *Acacia coriacea, Ipomoea costata* over dwarf shrubland (10–30%; <0.5 m) of *Triumfetta appendiculata* (Burrup Form) and *Stemodia grossa* over hummock grassland of *Triodia angusta* (Burrup form).
AcAeTe	Grove of low woodland (10–30%; <10 m) of *Acacia coriacea, Clerodendrum tomentosum, Alectryon oleifolius* subsp. *oleifolius* over low shrubland (10–30%) of *Aerva javanica* over open (10–30%) hummock grassland of *Triodia epactia* (Burrup form).
TsAcCa	Open heath (30–70% 1 m) of *Terminalia supranitifolia, Acacia coriacea, Phyllanthus ciccoides* over open grassland (2–10%) of *Cymbopogon ambiguus* with *Triodia epactia* (Burrup form) with herbs. There are scattered *Brachychiton acuminatus* and *Ehretia saligna.*
TapTe	Dwarf open heath (30–70% <0.5 m) of *Triumfetta appendiculata* (Burrup Form) over hummock grassland of *Triodia epactia* (Burrup form) and dense annual tall herbland of *Trichodesma zeylanicum.* There are scattered shrubs along the edge of the drainline.
TsAcTapTe(Ch)	Open low woodland (2–5% <10 m) of *Corymbia hamersleyana* over shrubland (10–30% 1–2 m) of *Terminalia supranitifolia, Acacia coriacea* over dwarf shrubland to open heath (10–40% <0.5 m) of *Triumfetta appendiculata* (Burrup Form) over hummock grassland of *Triodia epactia* (Burrup form).
TsAcIcTa	Mixed low heath (30–70% 1–2 m) of *Terminalia supranitifolia, Acacia coriacea, Ipomoea costata* with *Grevillea pyramidalis, Dichrostachys spicata* over hummock grassland of *Triodia angusta* (Burrup form) and herbs.
AbTeTa(Ev)	Mixed tall shrubland (10–30%) of *Acacia bivenosa* with occasional *Acacia coriacea* over open dwarf shrubland (2–10%; <0.5 m) of *Triumfetta appendiculata* (Burrup Form) with *Stemodia* grossaover hummock grassland of *Triodia epactia* (Burrup form) and *Triodia angusta* (Burrup form) associated with low woodland of *Eucalyptus victrix* which occurs immediately north of boundary.
Deeper Rocky Drainage Gullies	
BaAcTaCv	Low open woodland (2–10%; <10 m) of *Brachychiton acuminatus* with some *Terminalia canescents* over shrubland (10–30%; 1–2 m) of *Acacia coriacea* with *Scaevola* aff *spinescens* (glossy) over very open grassland of *Triodia angusta* (Burrup form) and very open sedges *Cyperus vaginatus* (2–10%) with herbs *Pluchea rubelliflora* and *Rhynchosia* sp.Burrup (82–1C).
EvAcTaCv	Low woodland (10–30%; <10 m) of *Eucalyptus victrix* over shrubland (10–30%; 1–2 m) of *Acacia coriacea* over very open (2–10%) hummock grassland of *Triodia angusta* (Burrup form) and sedgeland of *Cyperus vaginatus.*

Rockpiles, Ridges, Outcrops	
BaTsAc	Low woodland (10–30% <10 m) of *Brachychiton acuminatus* and *Terminalia supranitifolia* over shrubland (10–30% 1–2 m) of *Acacia coriacea* with *Ipomoea costata* and *Stylobasium spathulatum* over very open (2–10%) mixed grassland of *Triodia epactia* (Burrup form) and *Cymbopogon ambiguus*.
TsAcAe	Pocket of low, open woodland (2–10%; <5 m) of T*erminalia supranitifolia* over low shrubland (10–30%) *Acacia coriacea*, *Scaevola affspinescens* (glossy) with *Aerva javanica*
AcIcRm	Open to very low mixed woodland and shrubland (2–30% <2 m) of *Acacia coriacea*, *Ipomoea costata* with *Ficus virens*, *Rhagodia preissii obovata*, *Stylobasium spathulatum, Brachychiton acuminatus, Terminalia supranitifolia*, with occasional liane *Rhynchosia minima* (82–1C)
Undulating Coastal Dunes and Flats	
AbAuTeEte	Open scrub (30–80%; 2 m) of *Acacia bivenosa* over low open (2–10%) to shrubland (10–30%; 1 m) *Adriana urticoides* and *Aerva javanica* over hummock grassland of *Triodia epactia* (Burrup form) over herbland of *Euphorbia tannensis* subsp. *eremophila* with frequent *Swainsona Formosa*.
AeTeEte	Low shrubland (10–30%; <1 m) to low open heath (30–70%) of *Aerva javanica* over hummock grassland of *Triodia epactia* (Burrup form) herbland of *Euphorbia tannensisi*. Scattered (<2%) *Acacia bivenosa* (sometimes open 2–10%).
White Sand Beach and Dunes	
AeAuSl	Low shrubland (10–30%; 1 m) of *Aerva javanica* and *Adriana urticoides* over open tussock grassland (10–30%) of *Spinifex longifolius*, over herbland of S*wainsona pterostylis* and *Ptilotus villosiflorus*.
AcImAeTe	Shrubland (10–30%; 1–2 m) of *Acacia coriacea, Alectryon oleifolius* subsp. *oleifolius* and *Adriana urticoides* over low open heath (30–70%; <1 m) of *Indigofera monophylla* (Burrup form) and *Aerva javanica* over open (10–30%) hummock grassland of *Triodia epactia* (Burrup form).
Samphire Flat	
Hh(Sv)	Dwarf closed heath (70–100%; <0.5 m) of *Halosarcia halocnemoides* subsp. tenuis and *Halosarcia indica* over very open tussock grassland of *Sporobolus virginicus* (2–10%).
Valley	
EvAcTa	Open (2–10%) to low woodland (10–30%; <10 m) of *Eucalyptus victrix* over open shrubland (2–10% 1 m) of *Acacia coriacea* over hummock grassland of *Triodia angusta* (Burrup form). There are very scattered dwarf shrubs of *Indigofera trita*.
Ta(Ao)	Hummock grassland of *Triodia angusta* (Burrup form) with scattered (<2%) *Acacia orthocarpa* and scattered (<2%) dwarf shrubs of *Corchorus walcottii/Indigofera monophylla*.
AcoAbTe(Ch)	Scattered to very open low woodland (2–5% <10 m) of *Corymbia hamersleyana* over open (2–10% 1–2 m) of *Acacia colei, Acacia bivenosa* over hummock grassland of *Troidia epactia* (Burrup form) and patches of *Cymbopogon ambiguus*.