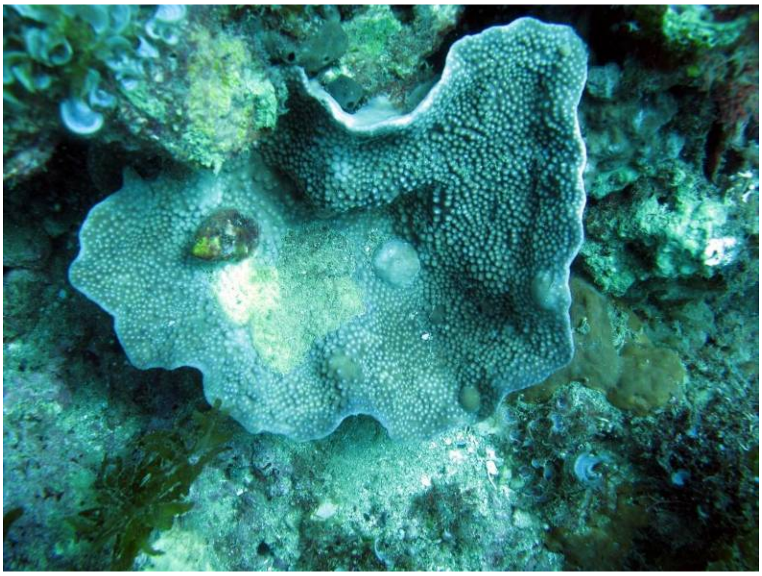
Port Hedland Outer Harbour Development



MARINE COASTAL INTERTIDAL BENTHIC HABITATS IMPACT ASSESSMENT

- WV05024
- Revision 1
- 7 April 2011

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The sole purpose of this report and the associated services performed by Sinclair Knight Merz ("SKM") is to assess the impacts of the proposed Outer Harbour Development on the coastal intertidal habitats at Port Hedland, in accordance with the scope of services set out in the contract between SKM and the Client. That scope of services, as described in this report, was developed with the Client.

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Executive Summary

Background

BHP Billiton Iron Ore operates a port in the Port Hedland region of Western Australia. In recent times, BHP Billiton Iron Ore has experienced unprecedented demand for iron ore from overseas markets and is now embarking on a development program to cater for this increased demand. BHP Billiton Iron Ore is currently investigating a number of port development options, one of which is to develop an outer harbour at Port Hedland. The marine component of the proposed Outer Harbour Development ('the Project') will include dredging and the development of a new jetty/wharf structure, berths and ship loading infrastructure.

The Project has the potential to impact upon marine benthic communities both directly (through construction of infrastructure and dredging) and indirectly (through dredging and spoil disposal plumes).

The Environmental Protection Authority (EPA) recognises the importance of benthic communities in contributing to marine ecological functions and provision of environmental services (EPA 2004). Consequently, the EPA has produced Environmental Assessment Guideline (EAG) No. 3, *Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment* (EPA 2009), and Draft EAG No. 7, *Marine Dredging Proposals* (EPA 2010), to provide advice on the considerations that must be addressed by any proponent of a development that may negatively impact upon the suite of environmental services and ecological functions supported by the benthic communities.

Objectives

The objectives of this marine coastal intertidal benthic habitats impact assessment are to:

- define the direct and indirect impacts related to the Project;
- predict the spatial extent of impacts to BPPH within State waters;
- calculate potential cumulative losses of benthic habitats within defined Local Assessment Units (LAUs);
- evaluate direct and indirect losses and impacts against the EPA's EAG No. 3 and No. 7;
- consider the impacts in a regional context to determine their ecological significance; and
- propose management strategies to minimise potential impacts to benthic communities.

Methods

This report covers marine coastal intertidal habitats and associated communities in State waters offshore from Port Hedland. All marine subtidal habitats along the coastline within the Project footprint, including inshore from Finucane Island, are covered by a separate intertidal BPPH assessment report (SKM 2011). A separate zonation of coastal intertidal habitats from subtidal habitats has been provided in the BPPH impact assessment process, as intertidal habitats will be influenced differently by sedimentation and turbidity impacts.

Predictive sediment plume modelling was undertaken by APASA to evaluate the extent of water quality perturbations resulting from proposed construction dredging and disposal activities. Perturbations included increased total suspended solid concentrations and elevated sedimentation rates. In addition, threshold criteria based on tolerances of hard corals to altered water quality conditions were applied to the modelling outputs such that impacts to benthic habitats and benthic communities could be determined.

A number of Local Assessment Units (LAUs) were proposed within State waters of the Project area. The LAUs relevant to this assessment are LAUs A, B, C, D and the Port Hedland Industrial LAU[1]. The proposed and predicted losses and impacts to marine coastal intertidal benthic habitats have been assessed in each LAU.

Outcomes

Direct loss of benthic primary producer habitat (BPPH) (1.7 ha; 0.3% of the Port Hedland Industrial LAU) will occur during construction of the marine infrastructure. When accounting for historical losses in the Port Hedland Industrial LAU (69 ha) this amounts to a total cumulative loss of 70.7 ha of BPPH within marine coastal intertidal benthic habitats for the Project, primarily due to historical losses.

The ecological significance of the losses of BPPH arising from the Project is considered to be minimal as the direct losses of coastal intertidal habitats associated with marine construction are very low.

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[1] Also known as the Port Hedland Industrial Area Management Unit, as identified in EPA (2001) Guidance Statement 1.

Contents

SKM

List of Figures

List of Tables

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1. Introduction

1.1. Project Overview

BHP Billiton Iron Ore operates a port in the Port Hedland region of Western Australia. The current port operations consist of processing, stockpiling and shiploading facilities at Nelson Point and Finucane Island (referred to as the Inner Harbour), located on opposite sides of the Port Hedland Harbour.

BHP Billiton Iron Ore is investigating a number of development options to further extend capacity of its port operations, one of which is to develop an outer harbour at Port Hedland.

The proposed Outer Harbour Development ('the Project') is expected to provide an additional nominal export capacity of approximately 240 Mtpa of iron ore from BHP Billiton Iron Ore's Port Hedland facilities, to be developed in stages.

The Project will involve the construction and operation of landside and marine infrastructure for the handling and export of iron ore. Landside development will include:

- rail connections from the existing BHP Billiton Iron Ore mainline to proposed stockyards at Boodarie;
- rail loops at Boodarie;
- stockyards at Boodarie; and
- an infrastructure corridor (including conveyors, access roadway and utilities) from the stockyards to a transfer station on Finucane Island that connects to a marine jetty.

Key marine structures and activities will include:

- an abutment, jetty and wharf;
- mooring and associated mooring dolphins;
- transfer station and deck;
- associated transfer stations, ore conveyors and ship loaders;
- dredging for berth pockets, basins and channels; and
- aids to navigation.

1.2. Study Objectives

The development of the Project will have direct and indirect impacts on marine coastal intertidal benthic habitats in the Port Hedland region. As required by the *Environmental Protection Act*, *1986*, an assessment of the environmental impacts arising from this development is to be made by BHP Billiton Iron Ore.

This document presents an assessment of the marine coastal intertidal benthic habitats and associated benthic communities that will or could be impacted by the Project, and an outline of the activities causing the impacts. Marine subtidal habitats in State waters within the project footprint are covered by a separate subtidal BPPH assessment report (SKM 2011). A separate zonation of coastal intertidal habitats from subtidal habitats has been provided in the BPPH impact assessment process, as intertidal habitats will be influenced differently by sedimentation and turbidity impacts.

1.3. Structure of this Report

This report comprises the following:

- **Section 2**: an overview of the legislative and policy framework for assessment of environmental impacts to marine habitats;
- **Section 3**: a description of the proposed construction and operation activities;
- **Section 4**: a summary of the marine coastal intertidal benthic habitats within the project footprint;
- **Section 5**: predictions of the likely behaviour and spatial distribution of dredge and dredge spoil disposal plumes and water quality threshold setting and rationale;
- **Section 7**: interpretation of sediment plume modelling outputs;
- **Section 8**: approach to assessment of impacts to benthic communities and benthic habitats;
- **Section 9**: predicted impacts to benthic communities and benthic habitats arising from construction dredging and disposal activities;
- **Section 10**: a summary of the environmental impact assessment provided in this document.

2. EPA Guidelines

The Environmental Protection Authority (EPA) issues Environmental Assessment Guidelines (EAGs) which assist in the protection and management of sensitive environments in Western Australia. There are two EAGs relevant to the environmental impact assessment undertaken in this report:

- EAG No. 3, *Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment*, provides guidance on assessing potential impacts, including cumulative irreversible loss and serious damage to benthic primary producer habitats in Western Australia's marine environment; and
- Draft EAG No. 7, *Marine Dredging Proposals*, has been designed to impart clarity and consistency to the information presented to the EPA for the environmental impact assessment of marine dredging proposals through the provision of a single assessment framework.

Although EAG 7 is a draft guideline, but BHP Billiton Iron Ore has addressed it in this impact assessment. A brief summary of each EAG is provided in the sub-sections below.

2.1. Environmental Assessment Guideline No. 3

The geographic scope of EAG No. 3 covers all coastal waters of Western Australia, from the highest water mark to the intertidal zone associated with the mainland, islands and emergent reefs to the depth maxima for benthic primary producer habitats in the subtidal zone of these waters.

In applying the intent of EAG No. 3 and ensuring that impact assessment is undertaken as intended by the EPA, a clear understanding of a number of terms is required:

- Benthic primary producer habitats are functional ecological communities that inhabit the seabed within which algae (e.g. macroalgae, turf and benthic microalgae), seagrass, mangroves, corals or mixtures of these groups are prominent components. Benthic primary producer habitats also include areas of seabed that can support these communities.
- Loss of benthic primary producer habitat would commonly be associated with activities such as excavation or burial. In almost all cases, these activities directly modify benthic primary producer habitat so significantly that impacted habitat would not be expected to recover to the pre-impact state and therefore the impact is irreversible.
- Serious damage refers to damage to benthic primary producer habitat that is effectively irreversible or, where recovery is predicted, it is not predicted to occur within a 5-year timeframe.

2.2. Draft Environmental Assessment Guideline No. 7

EAG No. 7 provides direction on assessment of the direct and indirect impacts of dredging on benthic communities and habitats. Specifically, the main focus of EAG No. 7 is:

- direct loss of benthic habitats and communities by removal or burial; and
- indirect impacts on benthic habitats and communities from the effects of sediments introduced to the water column by the dredging.

At a minimum, direct losses will occur within the footprints of dredged areas and some spoil grounds, and may extend to areas immediately surrounding infrastructure where acute or ongoing sediment-related impacts are expected to occur (e.g. sedimentation). Direct losses are considered irreversible unless a scientifically-sound case can be made for recovery within a timeframe of five years or less.

Indirect impacts generally occur as a consequence of the intensity, duration and frequency of sediment-related pressure imposed on benthic biota such as:

- Sediment in the water column (turbidity): reduces quality and quantity of light available at the seabed for photosynthesis, can clog feeding apparatus of filter feeders and deposit feeders and inhibit key ecological processes that occur in the water column (e.g. fertilisation of pelagic gametes, survivorship and competency of propagules).
- Sediment deposited on the benthos (sedimentation): smothers biota, can cause abrasion of exposed tissues, can alter sea bed load or produce other effects similar to those caused by turbidity.

3. Project Description

The Project will include the following key marine infrastructure:

- an abutment (on Finucane Island), jetty and wharf;
- mooring and associated mooring dolphins;
- associated transfer stations, ore conveyors and shiploaders;
- berth pockets, basins and channels; and
- aids to navigation.

The marine infrastructure for the offshore loading facility will be constructed from Finucane Island in an approximately northerly direction with a new wharf constructed adjacent to the existing shipping channel (approximately 4km offshore of Finucane Island). The marine infrastructure and activities are described in the following subsections and illustrated in **Figure 3.1**.

3.1. Marine Jetty

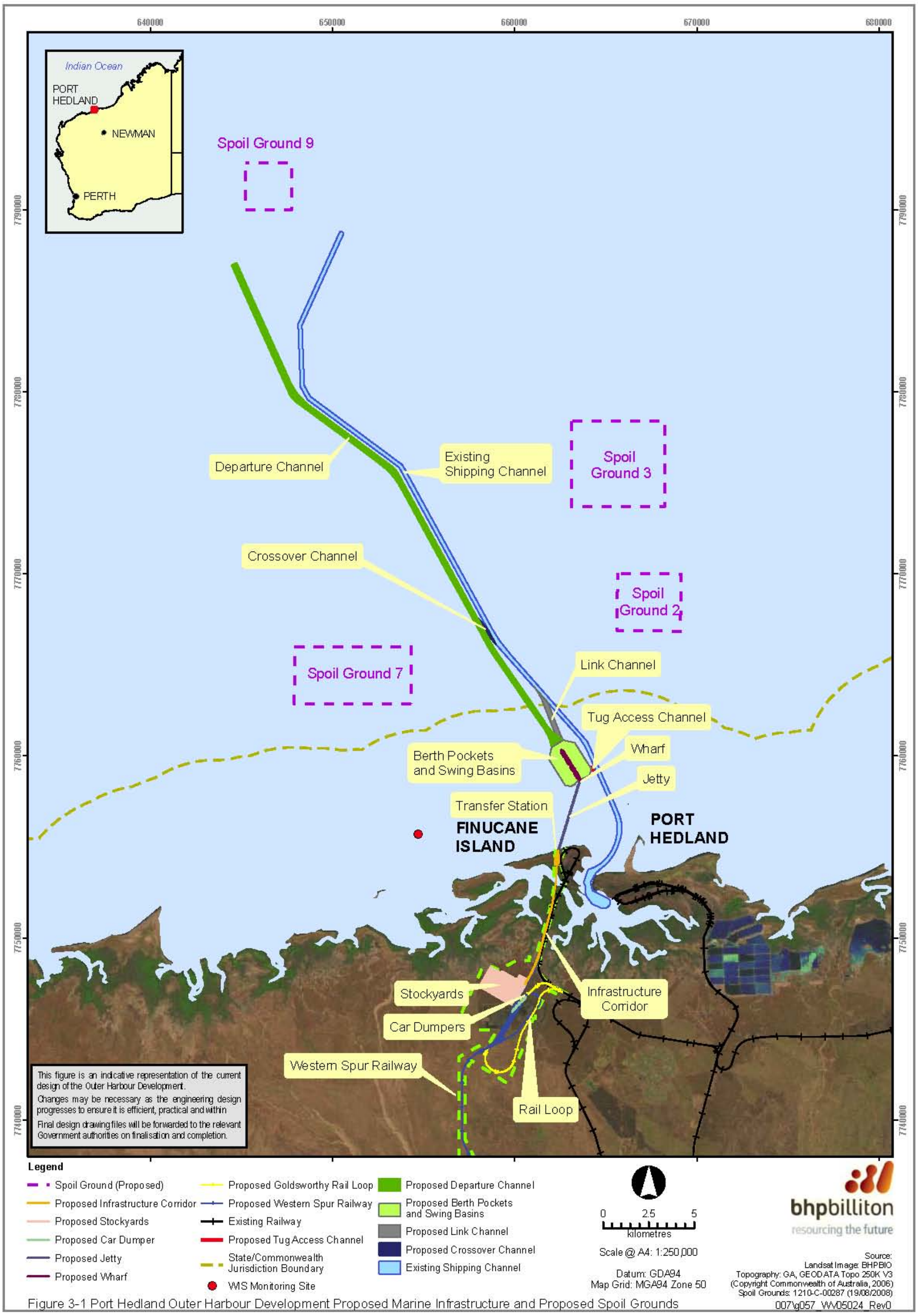
A steel piled jetty of approximately 4 km in length is proposed to be constructed from Finucane Island to the wharf. The jetty will support conveyors, maintenance services and a two lane roadway for vehicle access to the wharf. The jetty conveyors will be constructed to transfer ore material from the transfer station on Finucane Island to the transfer deck, then onto the wharf conveyors and into the shiploaders.

The passage of recreational water craft under the elevated jetty trestle will be permitted at controlled locations, for the purposes of safety.

3.2. Wharf Structure/Transfer Deck

The proposed wharf structure and associated berthing and mooring dolphins will be located approximately 4 km north of Finucane Island. The wharf will be approximately 2 km in length and will be designed to accommodate:

- shiploaders and shiploader rail system;
- access roadway and access walkways;
- maintenance bays;
- conveyor systems;
- cyclone tie down facilities, and
- support services (including amenities, offices etc).



- **Figure 3.1: Project Marine Infrastructure and Proposed Spoil Grounds**

Each development stage of wharf consists of two berths, with 8 berths in total. The proposed transfer deck will be located at the end of the jetty and will connect to the wharf structure. The transfer deck will provide services and support facilities for construction, operational and maintenance personnel.

3.3. Dredging and Spoil Disposal

The construction of the Project will require dredging to enable vessel access to the wharf and for loaded vessels to depart to deep water.

Dredging operations will create new berth pockets, swing/departure basins, a departure link channel to the existing shipping channel, a proposed departure channel, a cross-over link channel enabling access for departing, laden vessels from the Inner Harbour shipping channel into the new 34 km long departure channel and a tug access channel from the existing channel into the berth pockets.

The required depths will be approximately -22 m CD for the berth pockets, -23 m CD for the wharf footprint area, -11 m CD for the swing basins and -16 m CD for the departure basins, based upon a 250,000 Dry Weight Tonnes (DWT) vessel. The swing basins, departure basins, berth pockets and up to 3 km of the new departure channel will be located in State waters, with the remainder of the departure channel being in Commonwealth waters. The depths along the departure channel will range from approximately -15 m to -17 m CD.

The total volume of dredge spoil is estimated to be approximately 54 million cubic metres (Mm^3) of material, including over-dredging. The majority of material can be removed by a trailing suction hopper dredger (TSHD). A smaller percentage of the material is harder substrate and will require a cutter suction dredger (CSD). Based on the geotechnical studies completed to date there have been no areas identified in the dredging footprint that would necessitate blasting operations for material extraction. Dredging operations will involve a workforce of up to 160 persons and be conducted 24 hours per day, 7 days per week. It is proposed that dredging will occur in a staged manner, as follows:

- Dredging of berth pockets, eastern swing and departure basins, a tug access channel and a link channel to the existing channel to provide two loading berths.
- Dredging of the western swing and departure basins to provide two additional loading berths. This stage also includes the dredging works for the new 34 km departure channel and the crossover link channel.
- Dredging for the extension of the wharf with additional berth pockets and the swing and departure basins to accommodate another four loading berths.

The disposal of dredged material will be carried out in accordance with the Dredge and Spoil Disposal Management and Monitoring Plan. The suitability of a number of potential spoil locations has been investigated and there are three preferred offshore locations which have been identified as part of the application for a Commonwealth Sea Dumping Permit (SKM 2009a). A separate spoil ground selection phase study report to describe the history of the process has been undertaken (SKM 2009b). All of these offshore spoil grounds will be located in Commonwealth waters in depths greater than -10 m CD.

3.4. Construction of the Marine Infrastructure

The construction of the Project is intended to be phased to match BHP Billiton Iron Ore’s future operational and capacity requirements.

Construction of marine civil infrastructure will maximise the use of precast or prefabricated components. These components will be prepared offsite, shipped to Port Hedland and offloaded via a temporary offloading facility. Lay down areas on Finucane Island and at Boodarie will be utilised to temporarily store marine structures and equipment.

At the jetty abutment, a temporary platform consisting of a structural truss or frame and supported by the piles and crossheads will be utilised to drive successive piles and to install and erect the structures for the first 3 km of the jetty structure. Construction of the jetty trestle will involve jack up barges for piling. Jack up barges and cranes will be used for erecting and installing structures. Overall, a total of approximately 1,200 piles will be driven over a period of approximately 24 months for the jetty. The pile installation method may require some drilling.

Construction work is proposed 24 hours per day, 7 days per week, in favourable conditions. Piling activities will take place 24 hours a day, 7 days per week. It is proposed that physical piling is proposed to be 12 hours per day (7am to 7pm), 13 days per fortnight. Occasionally for safety reasons, there will be an allowance to continue piling activities up to 10 pm to accommodate the completion of a pile.

Approximately 40 to 50 marine vessels will be used including supply boats, tugs, barges and other marine craft that transport supplies, materials, equipment, consumables and personnel.

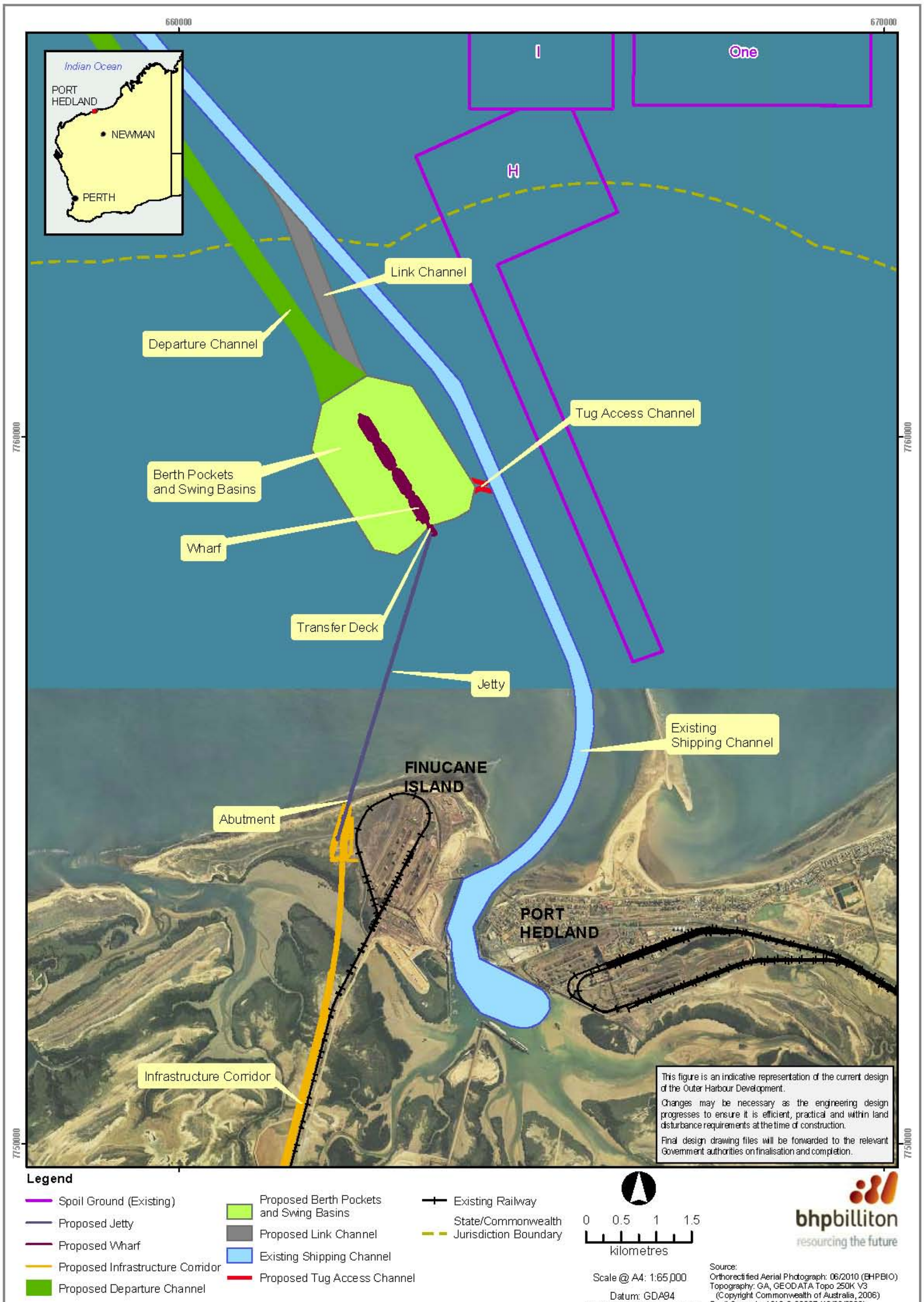


Figure 3-2 Port Hedland Outer Harbour Development Proposed Jetty and Wharf

- **Figure 3.2: Port Hedland Outer Harbour Development Proposed Jetty and Wharf**

3.5. Project Schedule

The dredging involved in this project will be undertaken in three stages. Volumes of material to be dredged include over-dredge allowance of 1 m. For the purposes of the impact assessment, and dredge modelling, an indicative schedule for the three stages and the volumes from each area are summarised in **Table 3.1**. BHP Billiton Iron Ore will continue to optimise the dredge programme during detailed design.

- **Table 3.1: Project Summary Schedule**

Dredge Area	Surface Area	Volume	Indicative Disposal Location Approximate Distribution
Basin and link to existing channel	2.25 km^2	22 Mm^3	50% Spoil Ground 3 50% Spoil Ground 7
Basin extension, new channel and cross-link to new channel	10.85 km^2	25 Mm^3	50% Spoil Ground 3 45% Spoil Ground 7 5% Spoil Ground 9
Basin extension	1.06 km^2	7 Mm^3	50% Spoil Ground 3 50% Spoil Ground 7
Total	**14.17 km^2**	**54 Mm^3**	

3.6. Operation of the Marine Infrastructure

Once completed, the proposed infrastructure will provide an additional nominal export capacity of approximately 240 Mtpa of iron ore from BHP Billiton Iron Ore's Port Hedland operations. The marine loading facility will be capable of berthing and loading 250,000 DWT vessels with a design provision for 320,000 DWT vessels to berth and load in the future. Operational activities pertinent to benthic habitats include:

- maintenance dredging of the access channel and navigational facilities;
- vessel movement with associated propeller wash and sediment disturbance;
- loading of iron ore; and
- wastes, discharges and spills associated with vessels and infrastructure.

Maintenance dredging and disposal of dredged material will be raised on an as-needed basis, as the need for maintenance dredging arises. Therefore, the impacts of maintenance dredging are not considered in this impact assessment.

Impacts of vessel movements, loading of iron ore and wastes/discharges/spills may result in disturbances to the benthic communities. However it is not predicted that irreversible or indirect impacts to benthic habitats, as described by EAG No. 3 and EAG No. 7, will result from vessel movements. As such, consideration of the disturbances from these activities is addressed in the Port

Hedland Proposed Outer Harbour Development: Draft Public Environmental Review / Impact Statement (PER/EIS) (BHPBIO 2011) and are not considered in the environmental impact assessment undertaken in this report.

4. Benthic Communities and Habitats

Section 4.1 summarises the studies that have been conducted within the coastal intertidal zone of the footprint of the Project. These studies have been used to define the benthic communities and habitat of the study area and include a desktop study and field survey. The results of these studies are detailed in **Sections 4.2** and **4.3**. Further detail on the existing marine environment, an overview of the benthic ecology of the region, and further details of all the studies completed for the benthic communities of Port Hedland are provided in the PER/EIS (BHPBIO 2011).

Provided below is a summary of the marine coastal intertidal benthic habitats and communities observed and mapped within nearshore State waters of the footprint for the Project and the studies undertaken to define distribution of benthic habitats. Further detail on the existing marine environment, an overview of the benthic ecology of the region, and description of the surveys undertaken are provided in the PER/EIS (BHPBIO 2011).

4.1. Studies Undertaken in Defining Benthic Habitat Distribution

Two studies have been undertaken to describe benthic habitats within the coastal intertidal zone. The coastal intertidal area is defined as the area between the Lowest Astronomical Tide (LAT) and the coast line[2], excluding the Port Hedland Inner Harbour.
The studies include:

- a desktop study of the coastal intertidal zone using satellite imagery; and
- a survey of the Finucane Island intertidal platform in February 2009 (SKM 2011).

4.1.1. Desktop Study

The benthic habitat within the coastal intertidal zone was assessed using digital imagery acquired of the study area. The digital imagery was a combination of imagery captured using satellites (QuickBird and WorldView-2 satellites) and aerial photography. The ideal images were those taken at low tide to assist in the delineation of habitat types, and for this reason the imagery used was captured over a range of dates. The aerial photography was taken in June 2010, while the satellite imagery was taken between January 2005 and December 2010. The imagery was orthorectified, colour balanced and PAN sharpened, then used to delineate between hard substrates (which included limestone ridges and intertidal platforms) and soft substrates (or sediments).

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[2] Geoscience Australia GEODATA Topo 250k V3, Commonwealth of Australia (GA), 2006

4.1.2. Survey of Finucane Island Intertidal Platform

A field assessment of benthic habitats was also undertaken during a spring low tide in February 2009 to assess the coastal intertidal habitat along the northern end of Finucane Island.

4.2. Benthic Habitats

Benthic habitats are comprised of either hard or soft substrates. Benthic primary producer habitat is benthic habitat that can or does support benthic primary producers (refer **Section 4.3**).

In the Port Hedland region, the distribution of benthic primary producers is strongly associated with areas of hard substrate and vertical relief associated with a series of limestone ridges, shoals and banks, as well as inshore rocky platforms that extend into the intertidal zone. Interspersed between these features are vast areas of coarse sandy sediment with extremely sparse coverage of biota, either benthic primary producers or non-benthic primary producers.

Within the coastal intertidal zone covered by the study area (total area: 21,691 ha), and outside of the Port Hedland Harbour entrance, 94% (20,397 ha) is sediments while 6% (1,294 ha) is hard substrate (**Table 4.1**).

- **Table 4.1: Benthic Habitats within the Coastal Intertidal Zone of the Project**

Habitat Category	Area (in ha)	Proportion (%)
Sediment	20,819	93.4
Hard substrate	1,364	6.1
Other	116	0.5
Total	**22,299**	**100**

4.3. Benthic Primary Producers

EAG No. 3 defines primary producers as: '*organisms (mainly green plants and algae) which can manufacture organic substances (food) from simple inorganic substances*.' (EPA 2009; p. 23).

Whilst the desktop analysis of the imagery allowed the delineation of hard and soft substrates, there was not sufficient resolution to identify specific benthic habitat types such as macroalgae and corals associated with these features. Therefore the hard substrate areas have been classed as mixed assemblages and assigned a community composition based on field investigations of the Finucane Island intertidal platform.

Investigations of the Finucane Island intertidal platform found three discernible zones:

- Lower Intertidal Zone – Characterised by predominantly exposed serpulid worm casing mounds (evidenced by sand casing mounds). This zone comprised mixed benthic primary producers (mainly macroalgae and hard corals) and non-benthic primary producers including motile and non-motile invertebrates (sponges, echinoderms and molluscs) were present.;

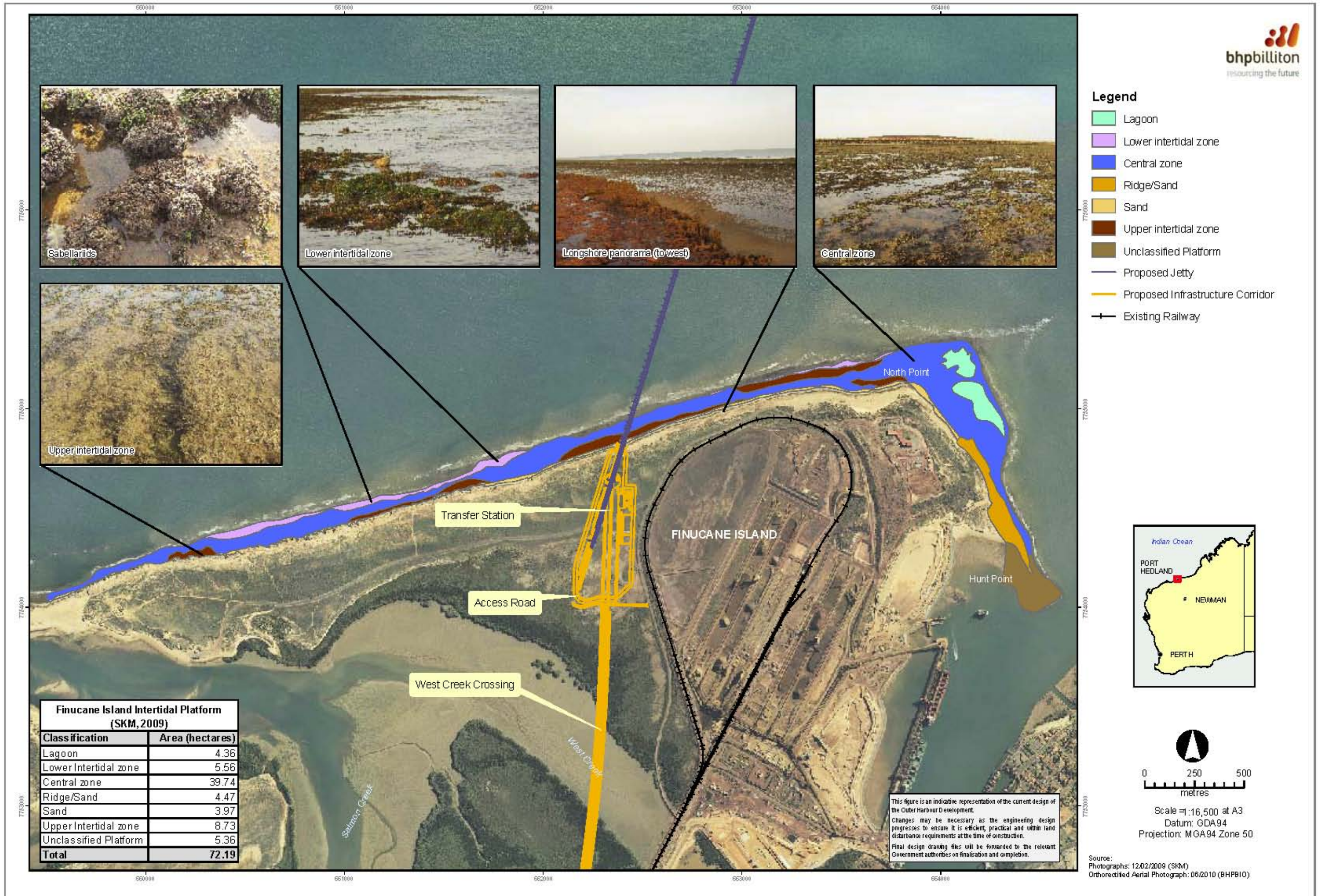
- Central Zone – Predominantly flat with numerous rock pool depressions. Dominant benthic primary producers in this zone were green and brown macroalgae, including the green macroalgal genera *Caulerpa*, *Halimeda*, and *Neomeris*, and the brown macroalgal genus *Sargassum*. Living or dead hard corals were conspicuously absent from the permanently submerged rock pools. Numerous motile invertebrates were observed in the rock pools, including octopi, crabs and starfish; and
- Upper Intertidal Zone – Gently sloped and marked by numerous rivulets running perpendicular to the shoreline. This was typically on the most landward zone, but was also observed close to the seaward ledge along part of the platform. This zone was more elevated than others and is likely to be exposed to air for longer durations. At the time of the survey, benthic primary producer coverage in this zone was restricted to turf algae on the flats and macroalgae in the rivulets.

The main factors influencing the distribution of biota on the platform can be summarised as:

- Height on intertidal zone: Diversity and density of benthic primary producers, including hard corals and macroalgae, were observed to be inversely related to platform height (greater densities observed at lower elevations). Hard corals were restricted to the lowest elevation sections of the platform, while only turf algae and macroalgae were present on the upper intertidal sections.
- Geology: The presence of rivulets is likely caused by water movement, either from rain or retreating sea water. Macroalgae were observed within the depressions of the rivulets, presumably due to a longer wetted duration than the surrounding flats that support turf algae.
- Sand accumulation and movement: Based on field observations and archival aerial imagery, a large section of the platform appeared to be inundated with sand for at least part of the year.

In addition to the zones described above, there were two large lagoons on the eastern (Hunt Point) end of Finucane Island which were up to 1 m deep, and supported numerous *Porites* colonies (hard coral). The colonies reached up to 1 m in diameter and were height limited due to lack of water coverage. These colonies have previously been monitored as part of the Port Hedland Port Authority and BHP Billiton Iron Ore environmental monitoring program (URS 2005; BHPBIO 2008; BHPBIO 2009). Two seagrass species, *Thalassia hemprichii* and *Halophila uninervis*, were also observed within these intertidal pools. Each species was present in low densities and of very limited areal coverage (less than or equivalent to 5 m^2).

The intertidal habitat on the seaward side of Finucane Island was mapped by interpretation of aerial photography and field investigations (**Figure 4.1**).



Finucane Island Intertidal Platform (SKM, 2009)

Classification	Area (hectares)
Lagoon	4.36
Lower Intertidal zone	5.56
Central zone	39.74
Ridge/Sand	4.47
Sand	3.97
Upper Intertidal zone	8.73
Unclassified Platform	5.36
Total	**72.19**

Figure 4-1 Intertidal Habitat on Finucane Island Platform

- **Figure 4.1: Intertidal Habitat on Finucane Island Platform**

5. Dredge Plume Modelling

Provided below is a summary of the approach to dredge plume modelling, and the modelling outputs used to predict impacts to benthic communities and habitats due to sediment plumes generated by construction dredging activities of the Project. For a more detailed account of this information, refer to APASA 2009.

Construction dredging for the Project includes the dredging of 54 Mm^3 of material to accommodate the construction of the channel and navigational facilities. Dredging is proposed to occur in a staged approach, resulting in 56 months of dredging over a five year period. A summary of the construction dredging activities, their timing and the associated volumes of material is provided in **Table 5.1**.

- **Table 5.1: Construction Dredging Activities, their Timing and Associated Volumes**

Stage	Year	Facilities	Duration (months)	Volume (Mm^3)
1	1–2	Berth pockets, eastern swing and departure basins, tug access channel, link channel	24	22
2	3–4	Western swing and departure basins, departure channel, crossover link channel	25	25
3	5	Extension for the wharf, additional berth pockets, swing and departure basins for four loading berths	7	7
Total			**56**	**54**

Due to the range of sediment material types present, a combination of dredging methods is required. It is proposed that a trailing suction hopper dredger (TSHD) will be used for unconsolidated materials, while harder materials will first require cutting and/or crushing using a cutter suction dredger (CSD). Once consolidated material has been crushed by the CSD, the material will be left on the seabed and subsequently removed by the TSHD.

In shallower areas to be dredged (such as the wharf), it is proposed that the CSD will likely be required to dredge materials initially so that the water depths are deep enough for the TSHD to operate in these areas. Where this is the case, the material dredged by the CSD will be stockpiled in deeper water within the dredge footprint, from where the TSHD will subsequently remove the material once water depths sufficient for access.

The dredging program will release sediment particles into the water column – suspended solids – resulting in a sediment plume. The extent of the sediment plume will be influenced by a range of factors including the dredging method, sediment characteristics of the area, ambient current movement, depth of water column and wind direction. The net effect of sediment particles being mobilised into the water column from the dredging will be an increase in total suspended solid (TSS) concentrations in the water column, and increased sedimentation rates because the higher load of sediment particles in the water column means that a higher amount of sediment will in turn fall out of the water column. Where the particles fall out is governed by the hydrodynamics and the particle size: in areas with strong currents particles will likely remain suspended while in calmer waters particles are more likely to fall out of suspension; larger sediment particles will fall out of suspension before smaller particles because they are heavier and more energy is required to keep them in suspension.

Asia Pacific ASA (APASA) were engaged to conduct modelling of the impacts from the sediment plume generated by the proposed dredging and spoil disposal activities, as indicated by the measures of TSS and sedimentation. Provided here is a summary of the modelling approach, objectives and findings.

5.1. Modelling Approach

Modelling of the sediment plume likely to be generated by construction dredging and disposal activities of the Project was based on detailed hydrodynamic and wave models in combination with a sediment transport model (SSFATE).

The sediment transport model accounts for the sinking rates of particles depending on their size (i.e. how long particles remain in suspension), sedimentation of particles (i.e. when and where particles drop out of the water column) and resuspension (i.e. the re-mobilisation of deposited dredged particles). The model computes the TSS concentration above background that directly results from dredging operations given the prevailing current (hydrodynamic) and wave conditions.

The model HYDROMAP was used to describe the flow-field conditions that are locally induced in the Port Hedland coastal region where tides and winds are the most important sources of hydrodynamic forcing. Validation of the hydrodynamic model demonstrated that HYDROMAP faithfully reproduced both shorter-term tidal magnitudes and directions, and longer-term transport along the coast.

The wave model used was the Simulating Waves Nearshore (SWAN) model, a regional model developed to simulate spatially-varying wave conditions over a wide domain. The large-sized model domain enabled sediments to be tracked over the long time span of the dredging and disposal construction activities of the Project. Validation of the SWAN model showed faithful reproduction of observed wave parameters across the full wave spectra.

The modelling domain[3] was sufficiently large to encompass the total area that may be affected by sediment plumes generated by the dredging and disposal activities, including cumulative impacts

[3] The modelling domain is the spatial extent represented by the predictive models.

due to resuspension of particles distant from the project activities. As such, the model domain spanned 131 km from east to west and 83 km from north to south.

Collectively, the current and wave models were demonstrated to be fit for the purpose of representing ambient current and wave fields as input to sediment fate modelling.

Data used to run the models included:

- detailed bathymetric data derived from the Light Detection and Ranging Survey (LiDAR) survey to provide high resolution information in areas proposed for dredging and disposal, and in surrounding areas a larger bathymetric grid resolution was used;
- wind and wave data for the area which was carefully selected to ensure seasonal and interannual variation in response to the Southern Oscillation Indices (i.e. La Niña and El Niño events) was represented in the sediment plume modelling;
- geotechnical information providing detail on the particle sizes of the sediments to be dredged in the proposed areas throughout the entire dredging depth profile; and
- details of the dredging method likely to be used including the types of dredges, predicted dredge logs (i.e. when, where and for how long a dredge will operate) and disposal of the dredge spoil.

5.2. Assumptions and Limitations

Assumptions and limitations of the modelling outputs included:

- the model computes the TSS concentration above background[4] levels that directly results from dredging operations given the prevailing current and wave conditions;
- TSS results are predicted for the near seabed level (0.5 to 1.5 m above the seabed) and are not depth averaged through the water column. This results in a worst case representation;
- the model computes the total sediment deposition above background levels; and
- resuspension of fine sediment is continuous throughout the dredging and may result in an over estimate of TSS through material being repeatedly resuspended.

Model output parameters were chosen so that near seabed predictions (0.5 to 1.5 m above bottom) for TSS concentrations were generated. It is these concentrations that are most applicable to the

[4] Background is a reference to natural conditions of the existing environment (already perturbated by current Port operations and activities).

impacts of the sediment plume on benthic primary producers and their habitats. The modelling results predict that the extent and severity of the sediment plume will be greatest just above the seabed. As such, the magnitude of impact predictions made for the Project are considerably greater than if predictions had been made as depth-averaged water column conditions, as is often the case with sediment plume modelling outputs.

To balance suitable temporal and spatial resolution while maintaining acceptable computational times, the minimum time step in the model was set at 30 minutes. This required the durations provided in the dredge logs to be adjusted to multiples of 30 minutes, with the exception of disposal operations, where 10 minute steps were required.

Background TSS is not included in the model results but is taken into account in the seasonal threshold values used to assess impacts on benthic primary producers and their habitats.. The model predicts that during the dredging program, the amount of fine sediment available as a source for resuspension will continually increase such that a sediment plume is generated well away from the immediate dredging and disposal areas.

An independent review of the sediment plume modelling undertaken by APASA was provided by RPS MetOcean. The results of this review can be found in APASA 2009.

5.3. Scenarios

Simulation scenarios were separated into four operations for dredging:

1) dredging by the TSHD of unconsolidated surface sediment;
2) dredging by the CSD of rock strata, with direct discharge back to the seabed;
3) dredging by the TSHD of the sediments deposited by the CSD; and
4) TSHD disposal at the disposal site from operations 1 and 3 above.

Initial modelling investigations were undertaken to test and compare the influence of disposal location on the outcome of this component of the operation. The study used two procedures to identify the optimum disposal location, in terms of the stability of deposited sediments and the potential for sediments to impinge upon adjacent sensitive habitats from either the initial release or from remobilisation of deposited sediments.

Firstly, predictions of shear-stress were calculated at seabed level throughout the domain shared by the hydrodynamic and wave models. This analysis provided an indication of the likely stability of spoil that is initially deposited within each area.

Secondly, disposal was simulated into areas that had been identified as potentially suitable for disposal of dredge spoil on the basis of logistic and environmental considerations. The results were primarily judged by examining overlap of the expected distributions of TSS and sedimentation with buffer areas that are designated around limestone ridges adjacent to the disposal areas.

Dredging and disposal activities associated with the Project were modelled for all of the development stages (1, 2 and 3) over the five-year duration of construction at approximately two month blocks of time for quality control and data security.

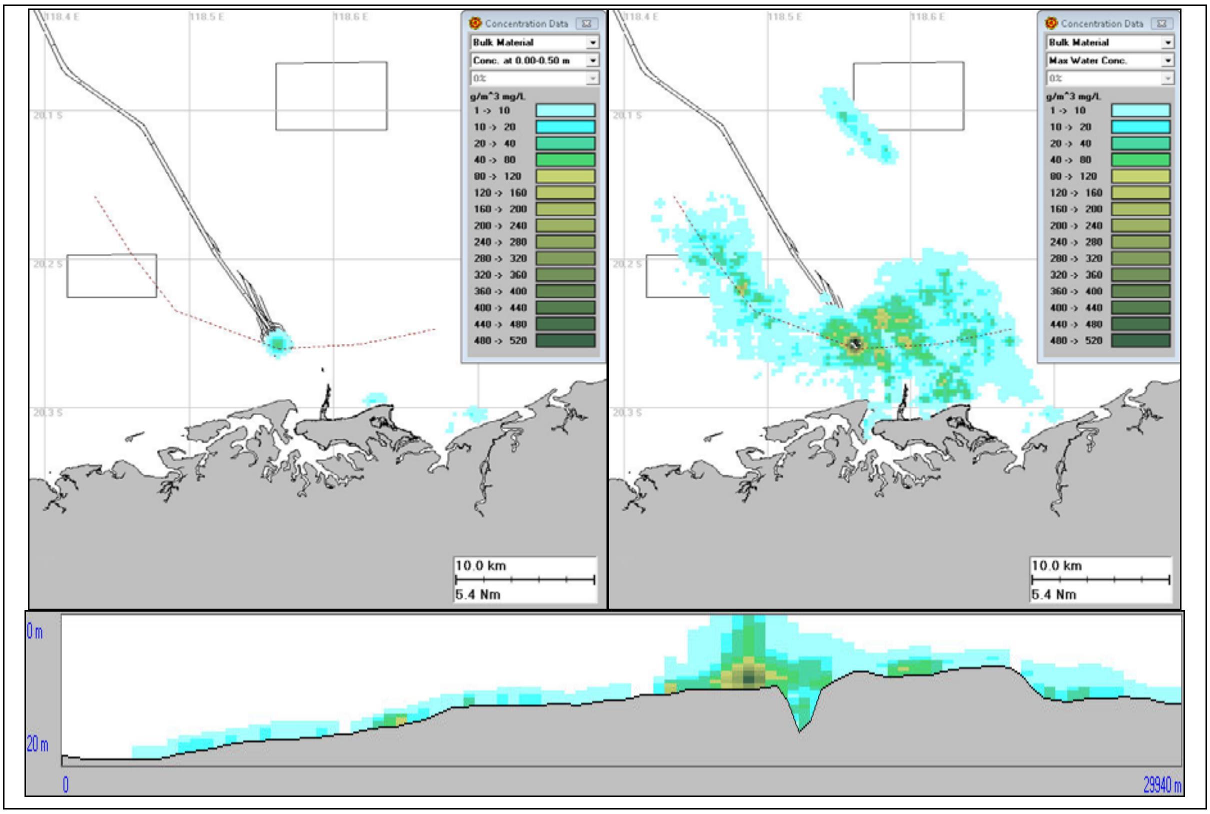
The modelled scenarios did not include proposed management actions targeted at reducing the extent of the dredging plume, therefore plume behaviour predicted by the model can be considered extremely conservative. The actual extent and severity of the altered water quality conditions resulting from the plume are likely to be less extreme than predicted by the model.

5.4. Modelling Results – Changes to TSS Concentrations

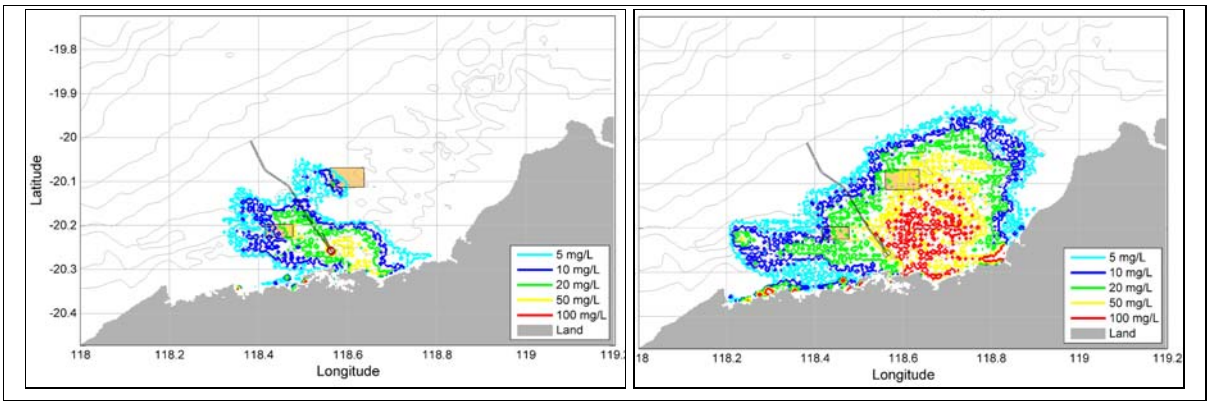
Dredging and disposal operations are likely to release a proportion of relatively fine sediments (clay, silt and fine sand) that will be subject to the current and wave climate. Heavier sediments and a proportion of the finer sediments are predicted to deposit around the dredging and disposal operations; finer sediments are predicted to deposit as thin layers for short durations over a wider area.

Sediment plumes are expected to disperse as a benthic plume (close to the seabed), undergoing cycles of settlement and resuspension due to tide and waves. In particular, the diurnal tide will induce cycles of sedimentation and resuspension for a portion of the finer sediments. While resuspended, these fine sediments will migrate with a tendency to distribute near the seabed. Sedimentation rates will also be subject to the prevailing waves, with a more irregular frequency.

The modelling demonstrated that the Project's dredging and spoil disposal activities will create a sediment plume characterised by increased total suspended solid concentrations and sedimentation rates relative to ambient conditions. The plume will be manifested at the surface by a relatively small, visible plume mainly restricted to within a few kilometres of the activities (**Figure 5.1**). Close to the seabed, the plume will be much larger in area and will be subject to regular resuspension of sediment. The areas where the sediment plume will be present will shift seasonally primarily due to changing conditions in the wave climate (**Figure 5.2**). The presence of the plume will persist throughout construction dredging activities, gradually dissipating over several weeks following their completion.

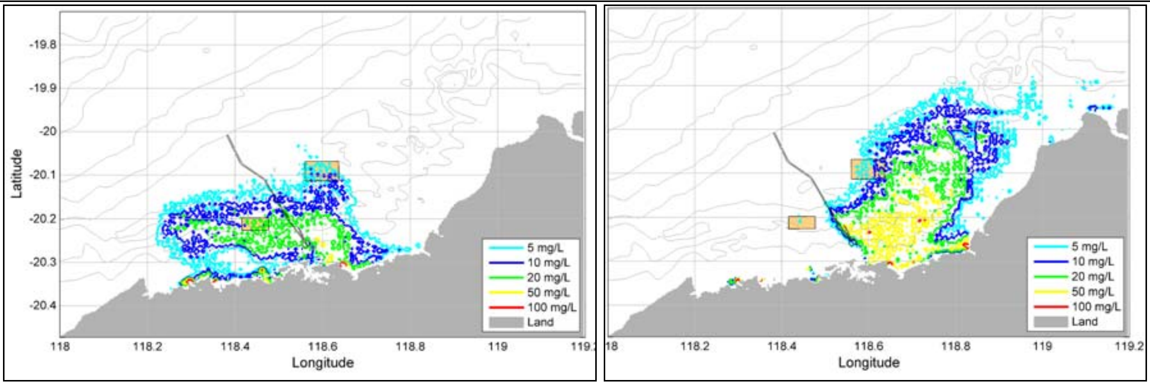


- **Figure 5.1: Sediment Plume Predictions as TSS Concentrations (in mg/L) at the Surface (top left), 0.5 m above the Seabed (top right) and a Bottom Profile (bottom)**



- **Figure 5.2: Stage 1 February to April (left) and October to December (right) of Year 1; 80th Percentile TSS Concentrations (in mg/L)**

Migration of sediment particles is predicted to vary over seasonal and shorter time scales. Flooding and ebbing tides will move sediment back and forwards over short durations and are predicted to spread sediment plumes in a generally onshore-offshore direction (south-east to north-west, respectively). In the longer term, the tropical dry (June to November) and wet (December to May) seasons create a directional change in the plume. A net migration of sediment to the west is indicated by the middle of the dry season, while during the wet season the plume is advected in an east and north-east direction (**Figure 5.3**).



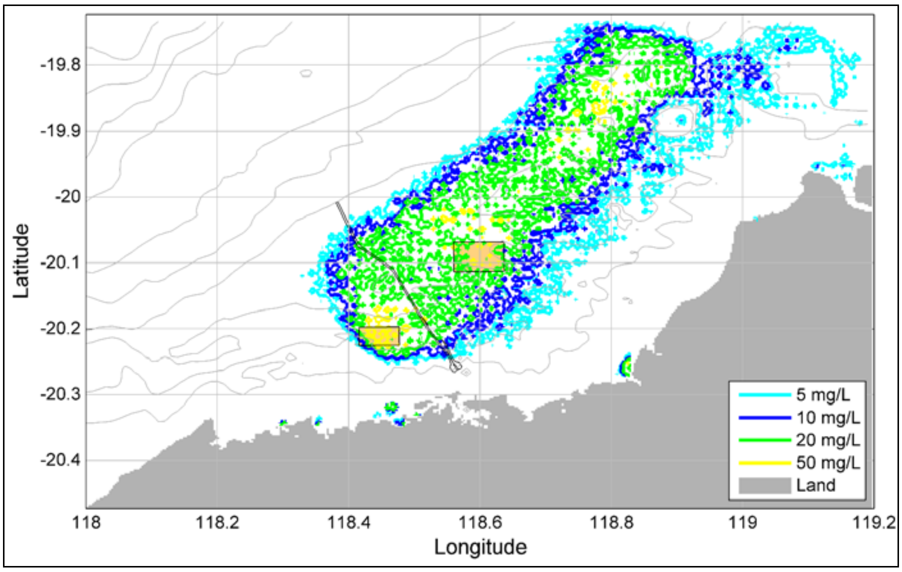
- **Figure 5.3: Stage 1 Dry Season (left) and Wet Season (right) of Year 1; 50th Percentile TSS Concentrations (in mg/L)**

The height of the wet season will bring a strong north-easterly movement to the plumes. The most extensive sediment plumes (extending over 80 km to the north-east of the source) with high TSS concentrations are predicted to occur during the wet season. The worst case wet season plume will be influenced by strong winds and large waves in combination with tidal currents, causing resuspension and dispersion of finer sediments. Late in the wet season the intensity of the plume to the north-east is expected to reduce, followed by a transitional period and reestablishment of the dry season pattern when the severity of high TSS concentrations abates.

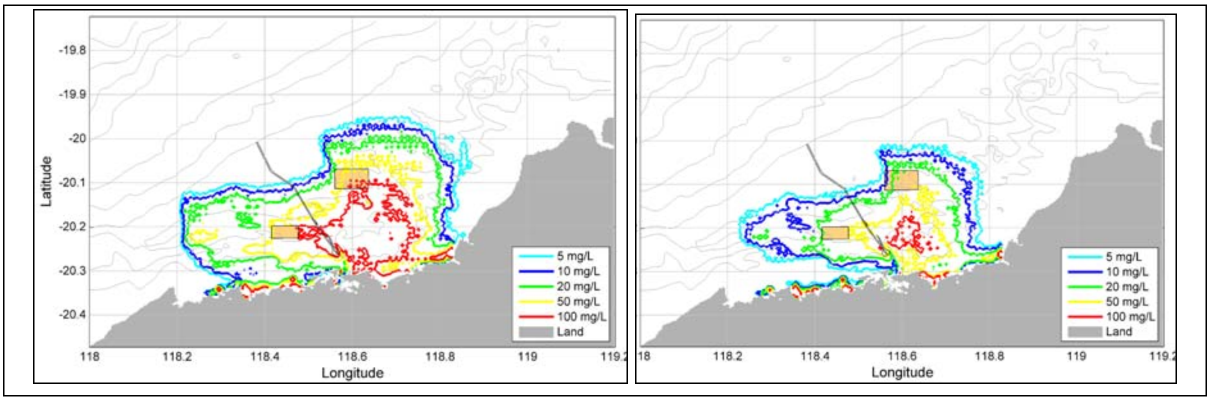
Highest TSS concentrations predicted during construction dredging and disposal activities of 160 mg/L are predicted to occur approximately 0.5 m to 1.5 m above the seabed. These high TSS concentrations are likely to be highly localised occurrences, forming in small pockets along the coast due to transport and trapping of material in these areas, and compounded by further resuspension.

Nearing the end of the main dredging component of Stage 2, the sediment plume is expected to shift further offshore due to the location of the dredging by this stage being concentrated in the outer part of the channel (**Figure 5.4**).

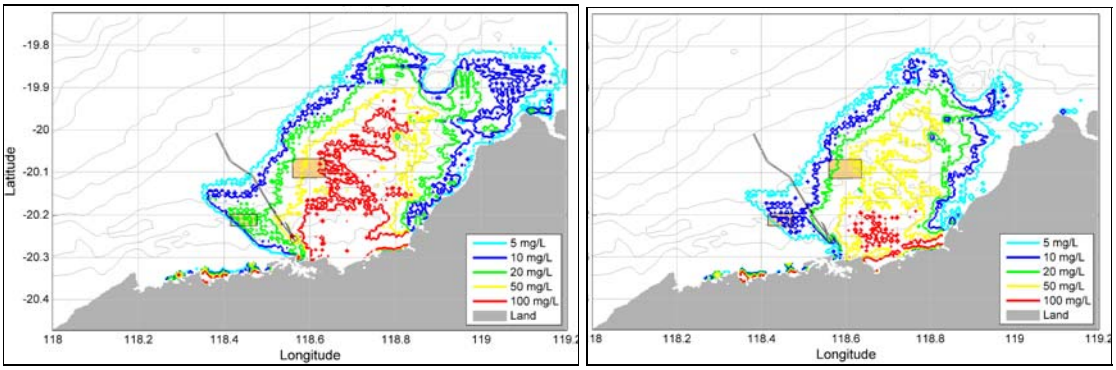
Stage 3 of construction dredging and disposal activities is proposed to commence 15 months after completion of Stage 2 dredging and disposal activities. Due to this delay, no cumulative effects from the previous dredging and disposal activities of Stages 1 and 2 are expected. The seasonal behaviour of the sediment plume within Stage 3 is predicted to be very similar to that of the previous stages, with westward migration in the dry season (**Figure 5.5**), and north-easterly migration in the wet season (**Figure 5.6**).



- **Figure 5.4: Stage 2 December to March of Year 4; 80th Percentile TSS Concentrations (in mg/L)**



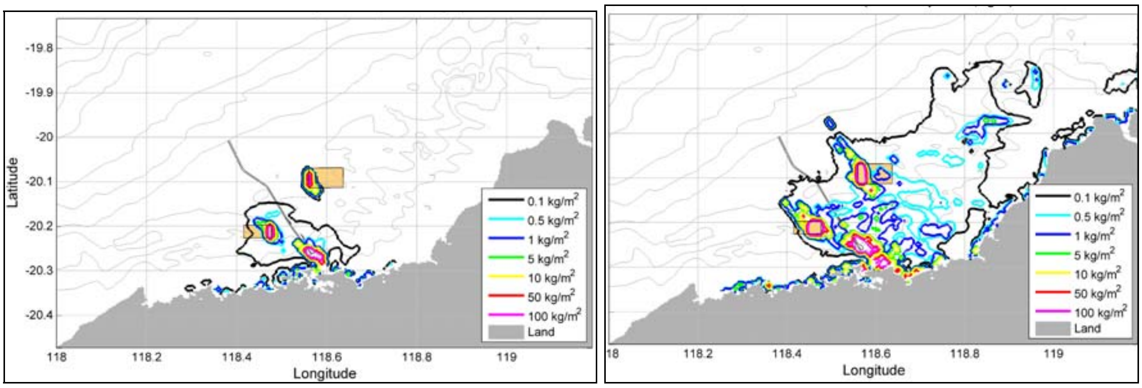
- **Figure 5.5: Dry Season – Stage 3 September to November of Year 5; 80th Percentile (left) and 50th (right) TSS Concentrations (in mg/L)**



- **Figure 5.6: Wet Season – Stage 3 November to December of Year 5; 80th Percentile (left) and 50th Percentile (right) TSS Concentrations (in mg/L)**

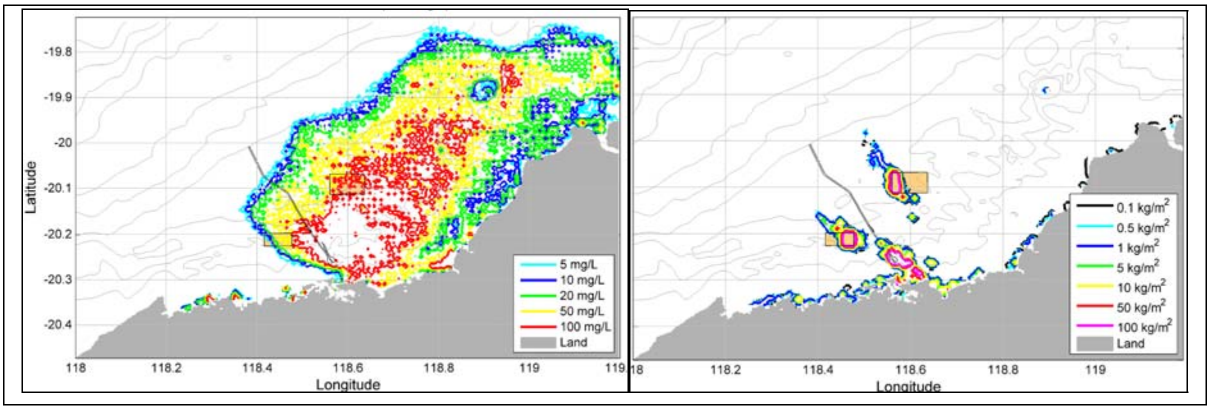
5.5. Modelling Results – Changes to Sedimentation Rates

Modelling of sediment deposition indicates that the majority of the sediment will sink from the surface within a short distance from the construction dredging and disposal activities. However, with increasing inputs and spreading of the sediment particles, predicted deposits will extend progressively further away from these areas (**Figure 5.7**).



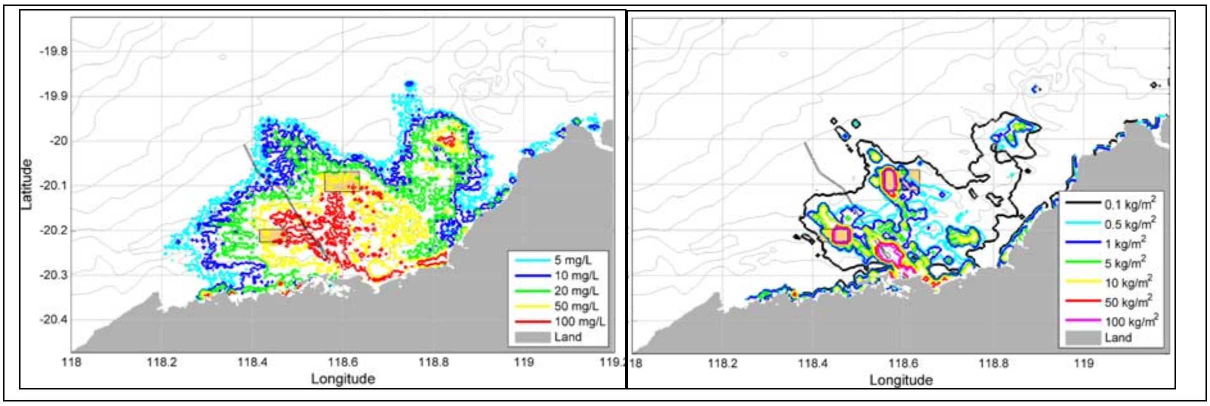
- **Figure 5.7: Stage 1 – 2 to 4 Months after Commencement (left) and 10 to 12 months later (right); 80th Percentile Sedimentation Rates (in kg/m^2)**

The seasonal patterns in the sediment plume indicated by sedimentation rates show a similar directional trend to that predicted by TSS concentrations: westerly during the dry season and north-easterly during the wet (**Figure 5.8**). Although the wet season conditions are predicted to result in greatest spread of increased sedimentation rates, the spatial extent of increased sedimentation greater than 0.1 kg/m^2 is expected to be notably smaller compared to the spread of increased TSS predictions.



- **Figure 5.8: Wet Season – Stage 1 December to January 80th Percentile TSS Concentrations (mg/L; left) and Sedimentation Rates (in kg/m^2; right)**

Although the predictions for sediment deposition over time indicate a progressive build-up of sediment particles, this trend is not expected to be consistent in the longer term. Periods of highly energetic hydrodynamic conditions that are predicted to create the most extensive sediment plumes as indicated by TSS concentrations show a far smaller plume distribution when modelled as sedimentation. This is because much of the fine sediments will either remain suspended during this period or will be resuspended. This will result in a time lag between the worst TSS plume conditions occurring, caused by particles resuspended into the water column, and the worst sedimentation conditions caused by less energetic conditions that allow sediment particles to settle out of the water column (**Figure 5.9**).

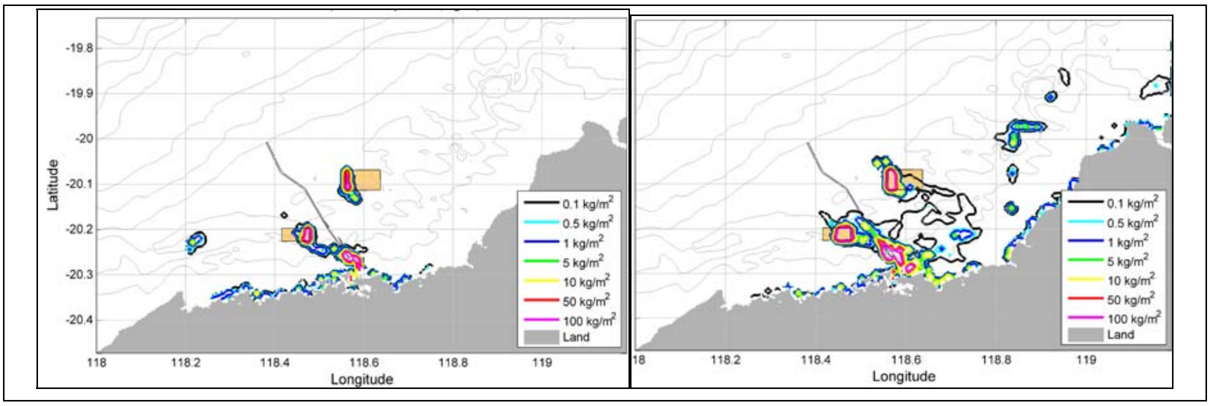


- **Figure 5.9: Wet to Dry Transition – Stage 1 April to June 80th Percentile TSS Concentrations (mg/L; left) and Sedimentation Rates (in kg/m^2; right)**

Areas of increased sedimentation are also predicted off Cape Thouin during the dry season and a shallow area near Turtle Island during the wet season (appearing as isolated patches in **Figure 5.10**, left and right respectively). Because these sites have shoaling bathymetry and therefore have naturally increased wave exposure and current speeds, they are predicted to experience repeated resuspension and settlement of sediment that accumulates in the areas.

The regular onshore-offshore pulsing of the tide is predicted to result in an onshore-offshore migration of suspended sediments released by the operations as well as resuspension of settled sediments. Because shear stresses decrease during slack tides at the end of the ebb and flood, there will be a resulting increase in the rate of settlement over the turning of the tides followed by an increased rate of resuspension as the tidal current speeds increase thereafter.

The relatively strong tidal currents in shallow areas are predicted to establish sufficient shear stress at the seabed to inhibit settlement of finer sediment particles (clays and silts) onto the seafloor and to resuspend a proportion of fine particles that had previously deposited. Resuspension of finer sediment particles is also predicted to generate secondary surface plumes and to contribute to sedimentation rates along the shallow coastal margin.



- **Figure 5.10: Stage 1 June to August (left) and Stage 2 February to April (right) 50th Percentile Sedimentation Rates (in kg/m^2)**

5.6. Summary of Predicted Impacts

Modelling of the construction dredging activities of the Project predicts that heavier sediment particles and a proportion of finer sediments will deposit around the dredging and disposal operations while finer sediments will deposit as thin layers, for short durations, over a wider area.

The model predicted smaller sediment particles (silts and clays) as being susceptible to the prevailing levels of shear stress arising from tidal currents, causing sediment plumes to migrate and disperse close the seabed (half a metre to a metre and a half above the bottom). In addition, daily cycles of settlement and resuspension of sediment are likely to occur due to the strong tides and influence of waves, with flooding and ebbing tides spreading the particles and plume in an onshore-offshore direction. Over seasons, a net migration of finer particles to the east and north-east in summer months and west in winter months is predicted.

6. Interpreting Sediment Plume Modelling Outputs

Full details of the approach used to interpret the sediment plume modelling outputs are detailed in SKM 2009c. Turbidity impacts (i.e. light climate) have not been assessed for the coastal intertidal zone as these impacts are related to the water column above the benthic habitat, and are therefore not predicted for the coastal intertidal zone where the benthic habitats are exposed to air twice daily on the low tide.

6.1. Predicting the Impacts on Hard Corals Using Sedimentation Thresholds

Sedimentation thresholds have been estimated from baseline data collected from the Weerdee monitoring site (refer the PER/EIS; **BHPBIO 2011**) located in State waters on gross sedimentation rates to determine the Zones of High and Moderate Impact. Sedimentation rates in both the wet and dry seasons have been taken into account when interrogating the model outputs.

Zones of High and Moderate Impact are based on the increases in sedimentation due to project activities in the State waters as described below:

- the Zone of High Impact is predicted to encompass areas which experience twice the maximum background mean daily gross sedimentation rates in any 14 day period; and
- the Zone of Moderate Impact is predicted to encompass areas which experience 1.1 times the maximum baseline mean daily gross sedimentation rates in any 14 day period.

Provided in **Table 6.1** are the daily sedimentation rates used to delineate the Zones of High and Moderate Impact. For further information on the development of these thresholds refer to SKM 2009c.

- **Table 6.1: Decision Rules Based on Sedimentation for Defining the Zones of High and Moderate Impact**

Sedimentation Factor and Zone	Daily Sedimentation Rates (kg/m^2/d)	
	Dry Season	Wet Season
Zone of Moderate Impact	0.07	0.73
Zone of High Impact	0.13	1.32

The data in **Table 6.1**is based on the particle size distribution data collected from within sediment traps, and next to the sediment traps at each site, for comparison. On the seafloor 95% of the sediment PSD was found to be greater than 150 µm compared to only approximately 3% of the sediment in the trap consisting of sediment particles greater than 150 µm. This indicates that the majority of sediment collected in the traps does not settle under normal metocean conditions (e.g. non-cyclonic conditions).

In the Zone of High Impact it is predicted that there will be a 100% loss of the benthic community underneath areas experiencing these sedimentation rates. Benthic communities within these areas are predicted to be completely smothered by elevated sediment loads resulting in irreversible losses.

In the Zone of Moderate Impact there is predicted to be sub-lethal impacts (e.g. reduced photosynthetic activity, increased mucous production) to benthic communities.

7. Approach to Impact Assessment

Provided in this section is an outline to the approach used in assessing the probable impacts to benthic communities and benthic habitats in the coastal intertidal zone. This assessment has been undertaken in keeping with EAGs No. 3 and No. 7 (EPA 2009, 2010; refer to **Section 2**). As such, boundaries for Local Assessment Units (LAUs) have been determined and impacts considered within each where increased sedimentation rates are predicted or removal/disposal of material is proposed. In addition, specific descriptions of the benthic ecology in the LAUs of interest with respect to the proposed project infrastructure, impacts arising from the proposed construction and operational activities and identified as ecologically significant to the region offshore of Port Hedland, are provided. Finally, a summary of historical losses of benthic habitat is also provided.

7.1. Definition of Impacts

The terms used in defining the nature of impacts to benthic communities and habitats are summarised in **Table 7.1**. In addition, the list of definitions provided by EAG No. 7 (EPA 2010; refer **Table 7.2**) have been adopted in this report.

- **Table 7.1: List of terms used to define impacts to benthic communities and benthic habitats**

Term	Definition
Loss	Direct removal or destruction of BPPH. Considered to be irreversible.
Damage	Alteration to the structure or function of a community.
Serious Damage	Timeframe for full recovery is expected to be longer than five years.
Minor Damage	Timeframe for full recovery is expected to be less than five years.

- **Table 7.2: List of definitions as described in Draft EAG No. 7**

Word or Phrase	Definition
Benthos	Benthos are the organisms which live on, in, or near the seabed
Dredge spoil	Seabed substrate material after it has been excavated from the seabed
Dredging	Activities that involve excavation of the seabed from the upper intertidal zone to the subtidal zone. Dredging in the sense of the EAG No. 7 means both dredging and dredge spoil disposal activities
Extent	The area over which an impact extends
Infrastructure	Is taken to mean the areas developed by dredging. Shipping channels, turning basins, berth pockets, pipeline trenches, spoil disposal sites, sub-sea mine areas and land reclamations are some examples of infrastructure
Irreversible	Lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less
Near real-time	Refers to a system for monitoring and interpreting data where the time lag between

Word or Phrase	Definition
	collecting monitoring data and responding is sufficiently short to be considered as immediate as practicable
Persistence	The period of time that an impact continues
Prediction	A forecast of future outcomes
Pressure threshold	Pressure thresholds signify a level of pressure (intensity, frequency and duration) that equates to a pre-defined level of impact in the biota of interest
Recoverable	See reversible
Reversible	A capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less
Severity	The degree of harm caused. For example, the degree of harm or severity of impact to biota could range from sub-lethal effects to mortality or loss
State coastal water	The State coastal waters extend three nautical miles seaward from the territorial baseline. EAG No. 7 applies to dredging or dredging-related impacts in these waters
Uncertainty	In relation to prediction is doubt or concern about the reliability of achieving predicted outcomes

Source: EPA (2010)

7.2. Dredging Induced Impacts on BPPH

EAG No. 7 (EPA 2010) focuses on the direct loss of benthic habitats and communities by removal or burial, and the indirect impacts on benthic habitats and communities from the effects of sediments introduced to the water column by dredging activities. Specifically, EAG No. 7 defines direct and indirect impacts as follows (EPA 2010; p. 13):

- direct impacts are, for the most part, coincident with the footprint of infrastructure and the areas immediately around the infrastructure; and
- indirect impacts arise when the pressure imposed by dredging exceeds the biota's natural tolerance to that type of pressure. The severity of indirect impacts will range from irreversible to readily-recoverable effects.

Section 8 presents BPPH loss assessments relating to direct loss of habitats and communities through removal due to construction of the marine infrastructure as proposed for the Project, and indirect losses due to sedimentation.

Indirect effects on benthic habitats and communities due to increased sedimentation rates resulting from dredging are presented in **Section 9**.

7.3. Definition of Impact Zones

Draft EAG No. 7 requests that impact zones due to marine construction activities be provided as follows (EPA 2010; p. 19):

- **Zone of High Impact (ZoHI)**: the area directly impacted (e.g. the channel and spoil disposal site) and a zone immediately about the proposed dredging and dumping areas where indirect impacts are predicted to be severe and irreversible. This zone defines the area where mortality of, and long term (i.e. months to years) serious damage to, biota and their habitats would be predicted. The impacts on the BPPHs and their habitats would be predicted. The impacts on the BPPHs within the ZoHI should be considered in the context of EAG No. 3;
- **Zone of Moderate Influence (ZoMI)**: abuts, and lies immediately outside of, the ZoHI. Within this zone sub-lethal effects on key benthic biota would be predicted, but there should be no long term damage to, or modification of, the benthic organism, the communities they form or the substrates on which they grow. Proponents should provide information about impacts in this zone both in the context of what would be impacted and what would be protected. The outer boundary of this zone is coincident with the inner boundary of the next zone, the Zone of Influence;
- **Zone of Influence (ZoI)**: the area where at some time during the proposed dredging and spoil disposal activities small changes in sediment-related environmental quality which are outside natural ranges might be expected however the intensity and duration is such that no detectable effects on benthic biota or their habitats should be experienced; and
- **Outer Boundary of the ZoI**: the point beyond which there should be no dredging (or spoil disposal) related changes from natural conditions. This is the area where it would be appropriate to establish suitable reference sites for the purpose of monitoring potential effects of dredging in the ZoHI, ZoMI and ZoI.

This approach has been applied in the assessment of impacts to BPPHs as undertaken in this report. Specifically, the decision rules that have been used to determine the zones and/or their boundaries as outlined above are summarised in **Table 7.3**. **Figure 7.1** illustrates the Zones of Impact and Influence within State waters for the proposed Project.

- **Table 7.3: Decision Rules Used to Determine the Zones of Impact and their Boundaries**

Zone	Description of Decision Rule
ZoHI	Anywhere that direct removal of BPPH is proposed to occur; and where twice the maximum background mean daily gross sedimentation rates is predicted to occur (refer **Section 6.1**).
ZoMI	Areas predicted to experience 1.1 times the maximum baseline mean daily gross sedimentation rates (refer **Section 6.1**).
ZoI	Water column TSS concentrations are greater than 5 mg/L above background concentrations
Outer Boundary of the ZoI	Water column TSS concentrations are 5 mg/L or less above background at any point in time

7.4. LAU Boundaries

The approach to assessing impacts to benthic communities and benthic habitats is spatially based. As defined in EAG No. 3 (EPA 2009; p. 7):

'*The EPA has termed the areas within which to calculate cumulative losses*[5] *Local Assessment Units (LAUs). The EPA is of a view that LAUs should normally be approximately 50 km^2*.'

In accordance with this approach, LAU boundaries have been proposed to enable the assessment of cumulative impacts to marine coastal intertidal benthic habitats due to the Project's construction activities. The LAUs and their boundaries have incorporated the following considerations:

- LAUs will be approximately 50 km^2 in area;
- as the LAUs are intended to assess impacts to coastal intertidal benthic habitats, the lowest astronomical tide mark forms the seaward boundary; and
- the coastline forms the landward boundary of the LAU.
- The Port Hedland Inner Harbour has been included within the Subtidal BPPH Impact Assessment (SKM 2011).

[5] Cumulative impact is defined as the sum of all irreversible loss of, and serious damage to, benthic primary producer habitat caused by human activities since European habitation of Western Australia. In this context, cumulative impacts do not include changes to benthic primary producer habitat caused by natural disturbances.

- **Figure 7.1: Zones of Impact and Influence within Coastal Intertidal Zone for the Proposed Outer Harbour Development**

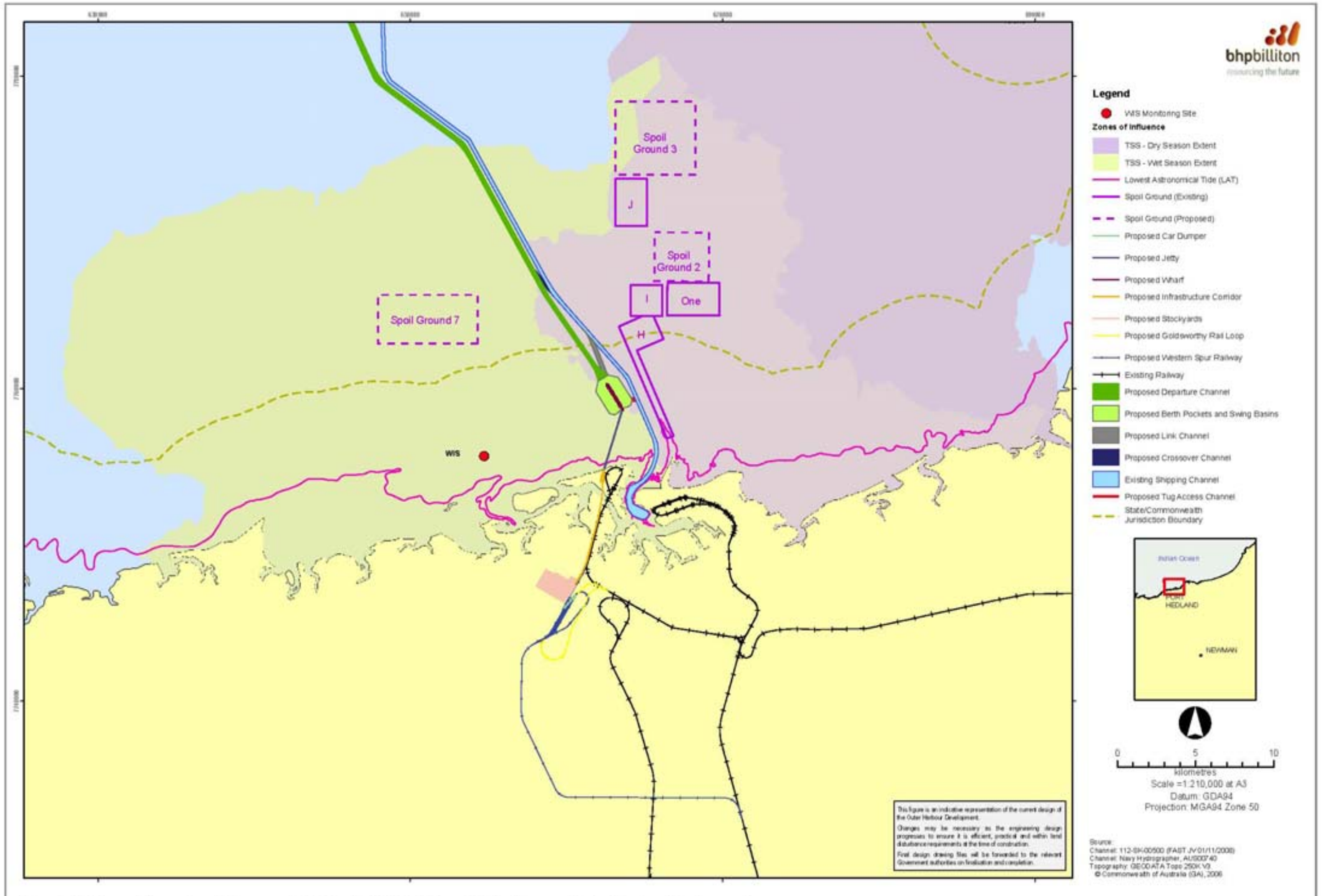


Figure 7-1 Zones of Impact and Influence within Coastal Intertidal Areas for the Proposed Outer Harbour Development

The proposed LAUs and their boundaries are presented in **Figure 7.2** and the total areas covered by each unit are provided in **Table 7.4**. The Port Hedland Industrial LAU[6] is an existing LAU within the region and as such has been incorporated into the assessment framework with slight changes to include the intertidal areas (that extend beyond the Port Hedland Industrial LAU) as illustrated in **Figure 7.2.**

- **Table 7.4: Proposed LAUs and their Boundaries for the Impact Assessment of Coastal Intertidal Benthic Habitats**

LAU	Area	
	in ha	in km^2
A	4,876	48.76
B	4,915	49.15
C	4,143	41.43
D	4,154	41.54
Port Hedland Industrial LAU	4,210	42.10

7.5. Benthic Ecology in LAUs

While analysis of the imagery allowed the delineation of hard and soft substrates, there was insufficient resolution to classify community composition of benthic habitats. Therefore hard substrates identified within the LAUs have been classified as mixed assemblages based on field investigations of the Finucane Island intertidal platform.

The majority of the coastal intertidal zone is soft substrate (93.4%), followed by mixed assemblages (6.1%; **Figure 7.3**) and other (0.5%) which consists of mangrove areas on the seaward side of the coast line delineation. A breakdown of the mixed assemblages is provided in **Table 7.5**.

- **Table 7.5: Breakdown of Habitat Types within the Five Coastal Intertidal LAUs**

LAU	Total Area (ha)	Mixed Assemblage (ha)	Mixed Assemblage (%)	Soft Substrate (ha)	Soft Substrate (%)	Other (ha)	Other (%)
A	4,876	267	5.5%	4,609	94.5%	–	–
B	4,915	550	11.2%	4,366	88.8%	–	–
C	4,143	118	2.9%	3,909	–	116.0	2.8%
D	4,154	0	0.0%	4,154	100.0%	–	–
PHI	4,210	498	10.2%	3,782	89.8%	–	–
Total	**22,299**	**1,364**	**6.1%**	**20,819**	**93.4%**	**116.0**	**0.5%**

[6] Previously known as the Port Hedland Industrial Area Management Unit, as identified in EPA (2001).

- **Figure 7.2: Boundaries of the Local Assessment Units (LAUs) for Assessment of Impacts to Coastal Intertidal Benthic Communities and Benthic Habitats for the Project**

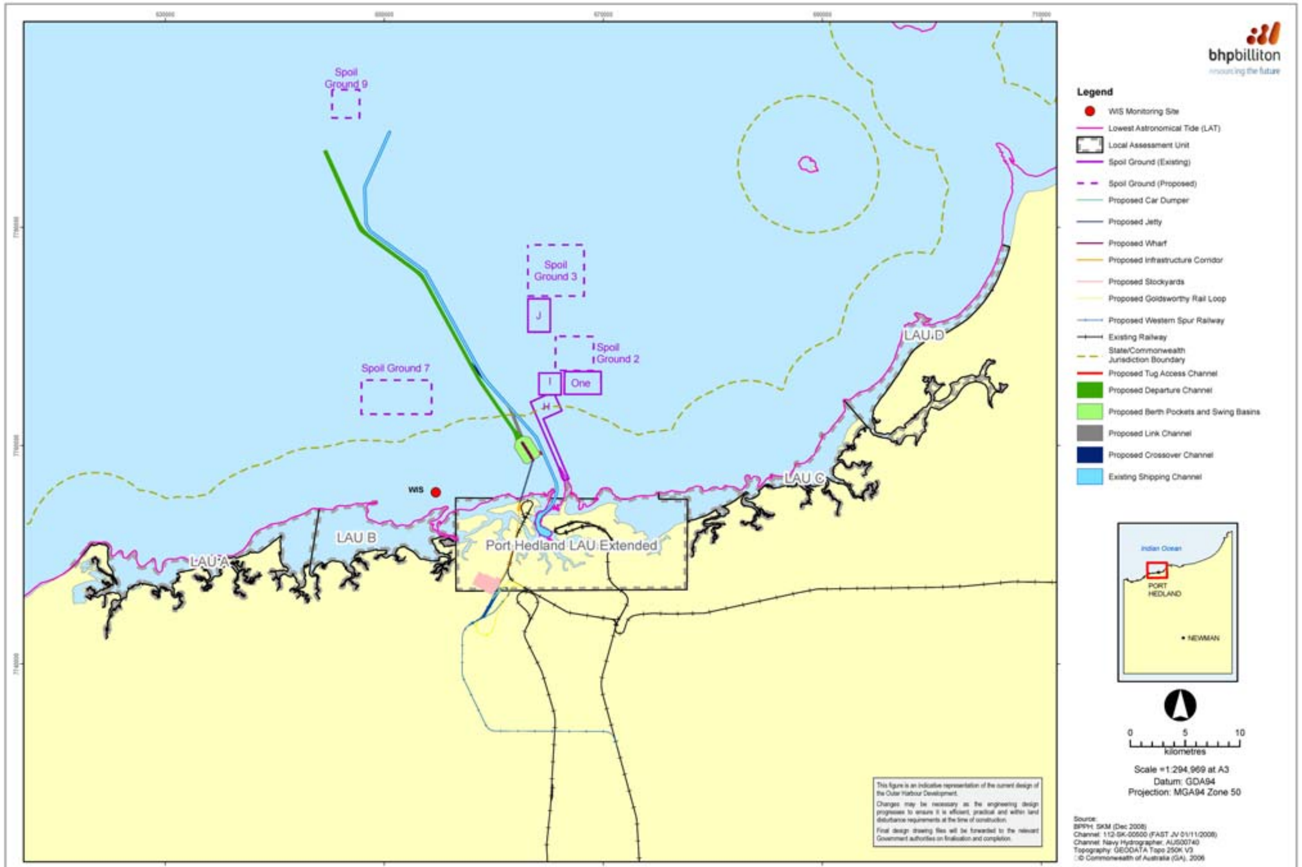


Figure 7-2 Boundaries of the Local Assessment Units (LAUs) for Assessment of Impacts to Coastal Intertidal Benthic Communities for the Proposed Outer Harbour Development

- **Figure 7.3: Distribution of Mixed Assemblage Habitat within the Coastal Intertidal Zone**

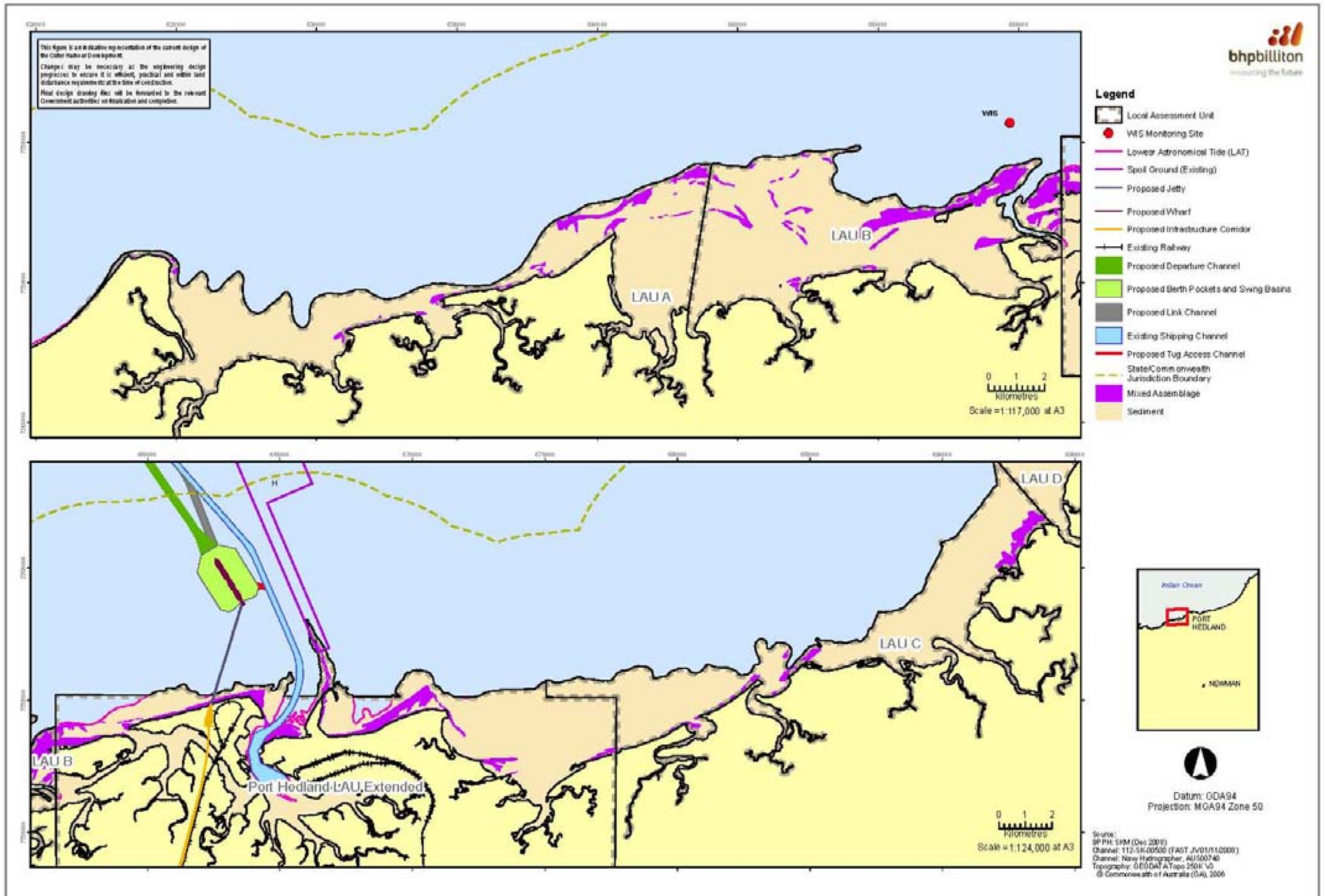


Figure 7-3 Mixed Assemblages Distribution within the Coastal Intertidal Area

8. Direct Impacts due to Marine Infrastructure

The impacts to BPPH described in this section are predicted to occur within the Zone of High Impact. As such, they are all considered irreversible.

The impacts detailed include historical impacts to BPPH (either estimated or recorded), the proposed BPPH losses due to removal during construction of the proposed marine infrastructure, and irreversible indirect impacts due to sedimentation caused by the dredging activities. Finally, measures proposed to manage impacts predicted during marine construction activities are summarised.

8.1. Historical Loss of BPPH

In estimating historical loss of BPPH, it has been assumed that permanent loss has occurred only where substrate has been physically removed (e.g. smothered during spoil disposal, or dredging undertaken).

Port Hedland has been an operating port since the late 1800's, when a jetty was created to service the pastoral industry of the eastern Pilbara. Prior to 1965, the harbour was crescent-shaped and had a maximum depth of 9 m at its widest point near the southern end (Hope Downs Management Services 2002). In 1965, with the development of the iron ore industry in the region, dredging began to alter the natural bathymetry of the harbour. Since that time, modifications have included:

- dredging of an approach channel to the harbour;
- reclamation of East Creek to accommodate developments at Nelson Point;
- construction of iron ore, salt and general cargo wharves; and
- dredging of a turning basin and berthing pockets.

Much of the development to date at Port Hedland has taken place inside the harbour, within the area of the tidal creek system, and impacts outside the mouth of the creek system have been confined to the shipping channel, spoil grounds and anchorages. Outside the harbour, dredge spoil has either been used for land reclamation or disposed of at the large spoil bank immediately to the east, north of the township. More recently, dredge spoil has been disposed of at offshore spoil grounds H, I and J and One. The build up of sediment in the harbour channel requires maintenance dredging to be conducted every three to four years. Capital dredging for new projects has also occurred.

The exact extent of historical BPPH loss due to previous dredging and spoil disposal activities is difficult to determine because there is no baseline habitat data or mapping available prior to the first dredging and disposal activities.

Spoil dredged from the entrance to the inner harbour was disposed to the east of the existing channel forming a large bank and an artificial sand spit to the north of the township, now known as 'spoil bank'. The spoil bank extends from the shore covering areas that would have been intertidal rocky platform and near shore bare sandy habitat. Again it is difficult to determine the exact extent of historical BPPH loss resulting from this spoil disposal. Assuming that the rocky intertidal area may have supported similar habitat to the area east of spoil bank, and the base of the spoil bank is approximately 1 km wide where it adjoins the beach to the north of the town, an area of approximately 5 to 10 ha may have been lost depending on the original width of the platform. Additionally due to the disposal of dredged material at 'spoil bank' the coastline now extends north from the intertidal platform and it is assumed that this area was also hard substrate that has been smothered.

A summary of the estimated historical coastal intertidal benthic habitat losses that have occurred within the Port Hedland Industrial LAU are provided in **Table 8.1**.

- **Table 8.1: Historical losses of BPPH (in ha and proportion (%) of the total area)**

LAU	Estimated Original Area (ha)	Historical Loss (ha)	Historical Loss (%)	EPA Category and Loss Threshold
Port Hedland Industrial	498	Spoil Bank Disposal: 69	13.9	E – 10%

8.2. Direct Loss due to Marine Infrastructure Footprint

Direct loss of BPPH within the coastal intertidal zone will occur in the Project footprint from construction of the jetty and abutment. The estimated areas of BPPH directly impacted by these activities are summarised in **Table 8.2.**

- **Table 8.2: Proposed Direct losses of BPPH (in ha and proportion (%) of the total area) due to the Marine Infrastructure Footprint**

LAU	Total Area of BPPH (ha)	Proposed Loss due to Infrastructure (ha)	Total Loss (ha)	Total Loss (%)	EPA Category and Loss Threshold
Port Hedland Industrial	498	Jetty & abutment: 0.36	1.7	0.3	E – 10%

- **Figure 8.1: Historical Coastal Intertidal BPPH Loss for the Proposed Outer Harbour Development**

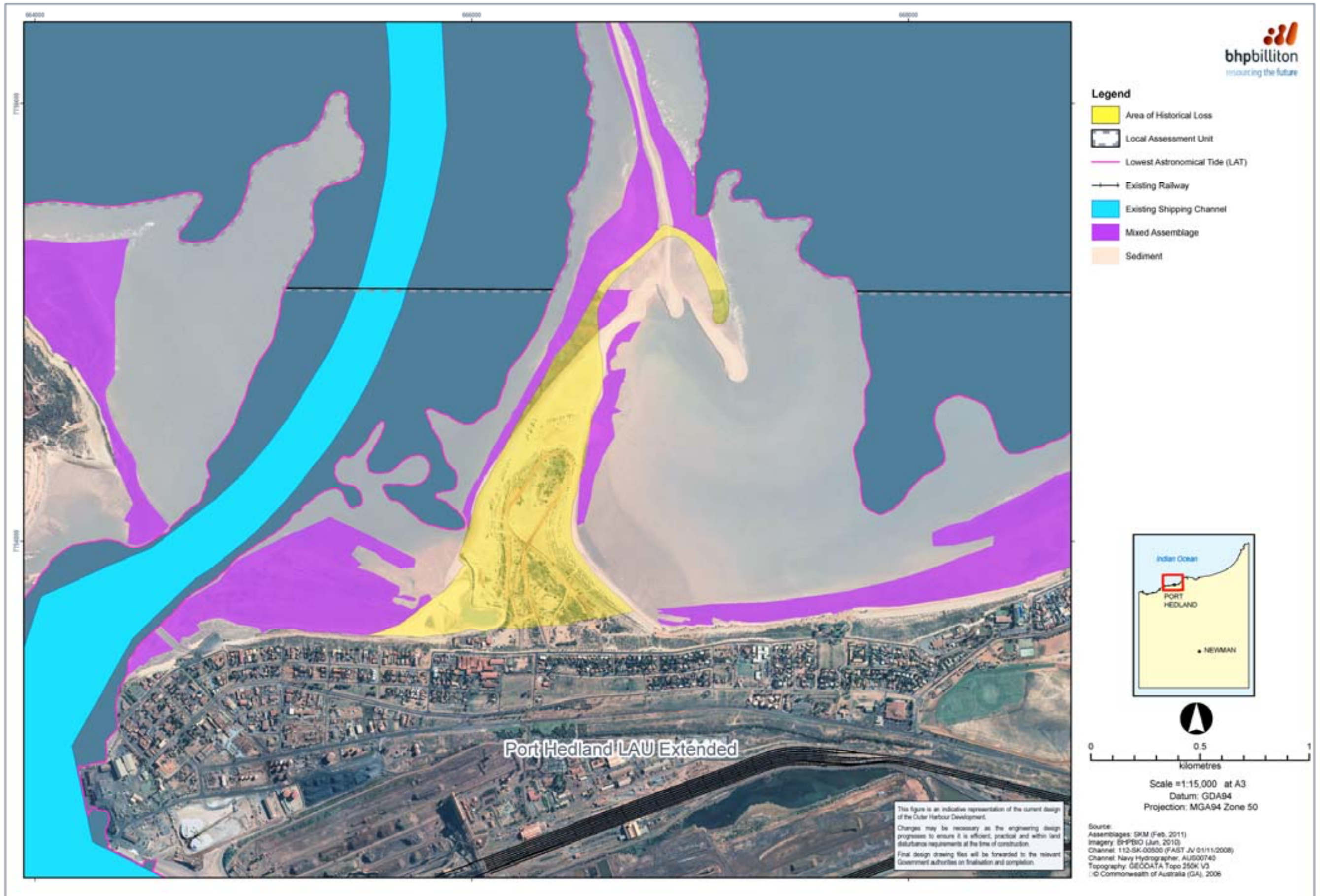


Figure 8-1 Historical BPPH Loss for the Proposed Outer Harbour Development

- **Figure 8.2: Direct Losses to Coastal Intertidal BPPH due to the Proposed Marine Infrastructure Footprint**

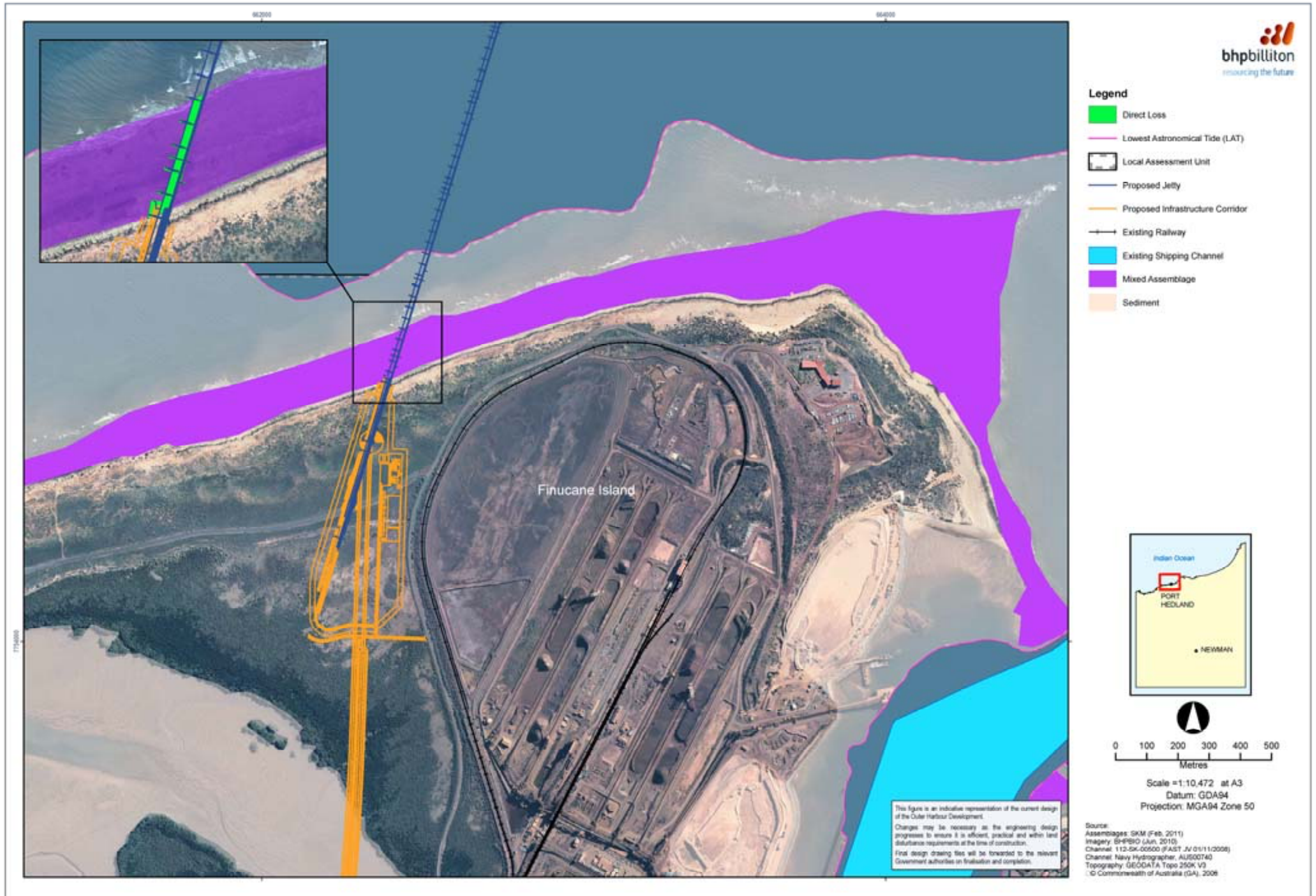


Figure 8-2 Direct Losses of BPPH due to the Proposed Marine Infrastructure Footprint

8.3. Indirect Loss due to Sedimentation

No indirect and irreversible loss of coastal intertidal BPPH is predicted to occur due to Project construction dredging activities (**Figure 8.3**).

8.4. Summary of BPPH Losses

A summary of the historical losses estimated for the region, direct losses proposed for removal during construction of the marine infrastructure, and irreversible indirect losses predicted to occur due to elevated sedimentation rates, is provided in **Table 8.3**.

These areas identified as hard substrate have been considered described as BPPH ‘mixed assemblages’ with 100% community cover. However, as described elsewhere (SKM 2011), *in situ* surveys of benthic habitats in the survey area have found that the actual percentage cover of mosaic benthic communities is much less than 100%. For example, the actual percent cover of mosaic benthic communities at Weerdee Island and Weerdee ridgeline ranged from 31.1% (macroalgae) to 1.6% (soft corals). Therefore while the predicted loss of BPPH within the coastal intertidal area is 99 ha, it is likely to be much less when considering known benthic community cover of hard substrate areas.

- **Figure 8.3: Predicted Irreversible Losses of Coastal Intertidal BPPH due to Elevated Sedimentation Rates**

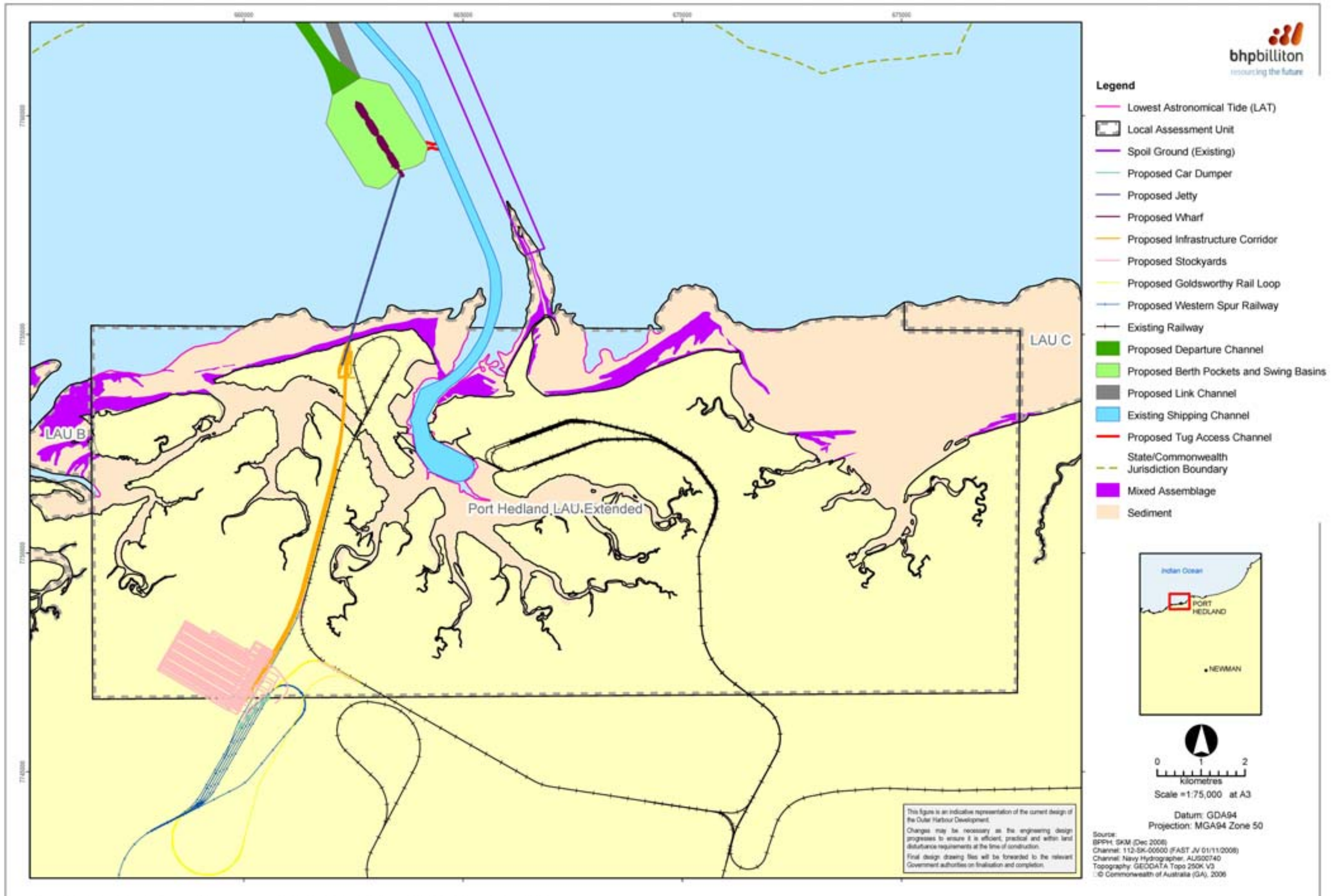


Figure 8-3 Predicted Irreversible Losses of BPPH due to Elevated Sedimentation Rates

- **Table 8.3: Total Cumulative Losses of Mixed Assemblage (in ha and proportion (%) of the total area) due to the Project**

LAU	Total Area of Mixed Assemblage (ha)	Historical Loss (ha)	Direct Loss (ha)	Indirect Loss (ha)	Total Loss (ha)	Total Loss (%)	EPA Category and Loss Threshold
Port Hedland Industrial	498	69	1.7	0	70.7	14.2	E – 10%
Totals	**498**	**69**	**1.7**	**0**	**70.7**	**14.2**	–

- **Figure 8.4: Estimated Coastal Intertidal BPPH Losses for the Proposed Outer Harbour Development**

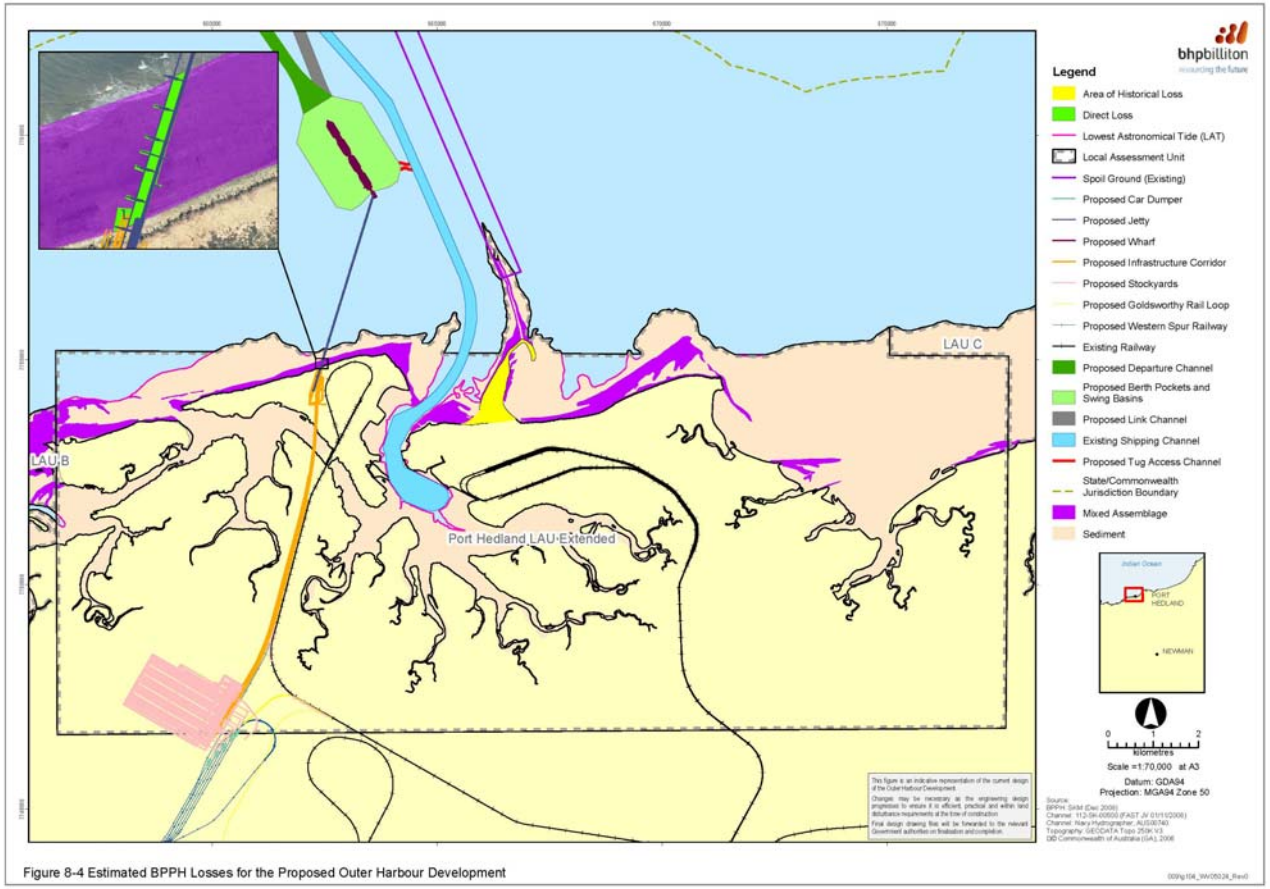


Figure 8-4 Estimated BPPH Losses for the Proposed Outer Harbour Development

8.5. Management of Impacts during Construction Dredging Activities

The management measures to be used for the minimisation of impacts to marine BPPH during the Project have been drawn from management plans for the Project.

The management measures recommended fall into five categories:

- control of dredging and disposal equipment and methods to minimise impacts to marine water quality;
- monitoring programs to assess the ongoing health of benthic communities during the program;
- water quality thresholds that will serve as triggers for responsive management action if exceeded; and
- location of spoil grounds to minimise impacts to BPPH supporting BPP communities.

These are detailed in the DSDMMP management strategies relevant to management of marine BPPH:

- **Section 7.1** Benthic Habitat Management;
- **Section 7.4** Spoil Ground Management; and
- **Section 7.5** Waste Management.

9. Indirect Impacts to BPPH

Indirect impacts on benthic habitats and communities from the effects of sedimentation introduced by dredging are discussed in this section. These impacts are predicted to occur within the ZoMI and as such all impacts discussed here are considered to be either sub-lethal or recoverable within a five-year timeframe.

9.1. Water Quality Conditions in the Zone of Moderate Impact

Water quality conditions in the ZoMI will include, where calmer water conditions are experienced, elevated sedimentation rates (**Figure 9.1**).

As detailed in **Section 5**, modelling of the sediment plume predicted that heavier sediment particles and a proportion of finer sediments will deposit around the dredging and disposal operations while finer sediments will deposit as thin layers, for short durations, over a wider area. In particular, daily cycles of settlement and resuspension of sediment in the broader area are likely to occur due to the strong tides and influence of waves. This thinner layer of sediments that is deposited, resuspended and dispersed on a daily basis is the driver of indirect impacts in the ZoMI.

Indirect impacts to the benthic ecology due to this thin layer of sediments redistributed on a daily basis will affect both benthic primary producers (BPPs) and non benthic primary producers (non-BPPs).

9.2. Indirect Impacts to BPPs

The majority of sedimentary material that will be suspended in the water column within the ZoMI will be fine (less than 64 µm) sediment particles that are easily resuspended through tide and wave action. As such, there will be times during the day when suspended materials will fall from the water column and deposit on the benthos (e.g. during slack tide) and other times when the deposited material will be resuspended into the water column making the waters more turbid (e.g. during ebb tides). Given that tidal action is diurnal, this pattern will occur twice a day and possibly more if coincident wave conditions are energetic.

As a result of the predicted dynamic movement of fine sediment particles within the ZoMI, BPPs will experience windows of clearer water conditions, and removal of deposited sediment materials, on at least a daily basis.

Although the water column will be more turbid than background, and although a fine layer of silt will be depositing on BPPs within this zone, the suspended and deposited material will be very mobile. This will create an environment that allows BPPs within the ZoMI to photosynthesise. It is due to this regular opportunity to photosynthesise that no irreversible losses due to sedimentation are predicted for BPPs in the areas demarcated by the ZoMI.

- **Figure 9.1: Zone of Moderate Impact Predicted for the Proposed Outer Harbour Development**

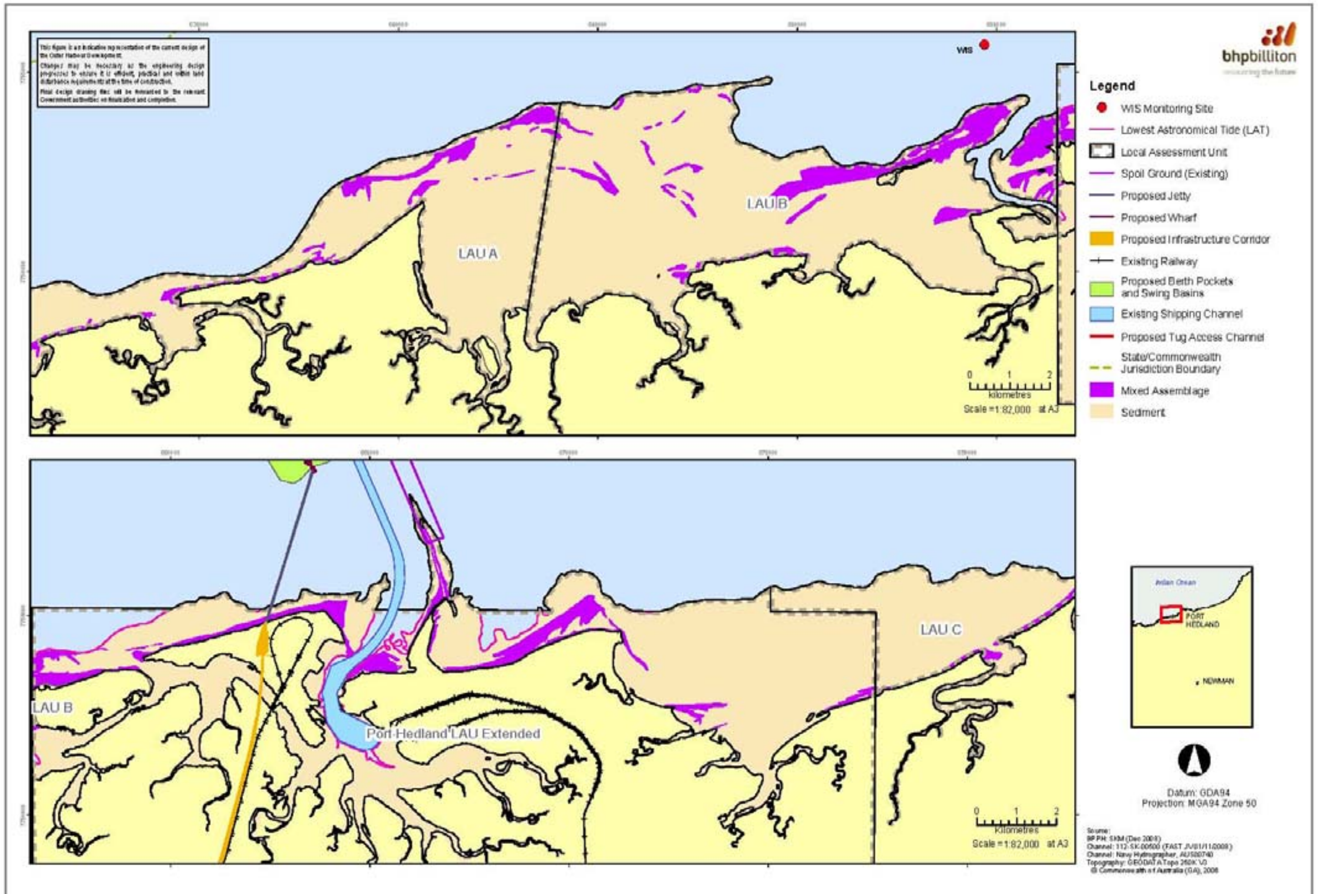


Figure 9-1 Zone of Moderate Impact Predicted for the Proposed Outer Harbour Development

9.3. Summary of BPPH Impacts

The benthic communities within the ZoMI will experience increased sedimentation rates, however it is due to the frequent (twice-daily) resuspension and redistribution of sedimentary material that will provide temporary relief from deposited materials.

Due to this frequent relief of fine sedimentary material within the ZoMI, it is predicted that BPPs will not suffer indirect losses in this zone, and at most, sub-lethal impacts such as reduced photosynthetic activity, increased mucus production and decreased filtration rates may occur.

10. Benthic Habitat Loss Assessment Summary

Outcomes of the assessment of impacts to marine coastal intertidal benthic habitats due to the Project are provided below, including a summary of the information underpinning the assessment.

10.1. Irreversible BPPH Losses

The areas of estimated loss occur within and in close proximity to the dredging activities.

Physical seabed disturbance from dredging will result in the removal and direct loss of 1.7 ha of BPPH within the coastal intertidal zone. No indirect losses are predicted.

The cumulative irreversible loss of coastal intertidal BPPH from both historical and proposed losses is predicted to be 14.2% (70.7 ha) in the Port Hedland Industrial LAU.

This level of cumulative irreversible loss is unavoidable if the Project is to proceed as proposed, as the infrastructure footprint has been designed to minimise the potential BPPH losses.

10.2. Ecological Significance of Losses

The ecological significance of estimated benthic community losses is minimal, as the direct losses of coastal intertidal BPPH associated with the marine infrastructure represent a very small fraction of the total BPPH of this type in the Port Hedland region.

10.3. Predicted Environmental Outcomes

Direct loss of coastal intertidal BPPH (1.7 ha; 0.3% of the Port Hedland Industrial LAU) will be removed during construction of the jetty and abutment. When accounting for historical losses in the Port Hedland Industrial LAU (69 ha) this amounts to a cumulative loss of coastal intertidal BPPH for the Project of 70.7 ha of BPPH.

The ecological significance of the losses of BPPH arising from the Project is considered to be minimal as the direct losses of coastal intertidal habitats associated with marine construction are very low.

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