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Section 10
Marine Impacts and Management

10 Marine Impact Assessment and Management

10.1 Introduction

This chapter provides an assessment of impacts that the construction and operation of the proposed Outer Harbour Development will potentially have on the marine environment. Included in the assessment is consideration of the management objectives for each environmental factor at risk; design, mitigation and management measures proposed to reduce impacts; an evaluation of the significance of the residual impacts in light of the management approach; and the environmental outcomes arising from each of the evaluated project aspects.

The coastal environment of the Pilbara region in the vicinity of the project is characterised by marine habitat of vast sandy plains and a series of low relief offshore limestone ridgelines supporting sparse mosaic benthic communities. The coastline in the region is predominantly rocky shorelines, sandy beaches, wide shallow sand and mud flats with mangrove lined tidal creeks.

Several historical activities have considerably altered the bathymetry and coastal processes of the proposed Outer Harbour Development area, including historical dredging of a shipping channel, creation of several offshore spoil grounds and the deposition of spoil material into a large sand bar which has now become a prominent feature of Port Hedland's coastline. In addition, dredging of an approach channel, turning basins and berthing pockets for the Inner Harbour facilities has resulted in high levels of vessel movement and shipping traffic for the Port Hedland Harbour.

The proposed marine infrastructure for the project extends offshore from Finucane Island in a northerly direction with a jetty approximately 4 km in length terminating in a 2 km wharf, with a navigational channel approximately 34 km in length.

Specifically, the marine infrastructure components comprise:

- an access jetty structure, including abutment works;
- a deck for the transfer station where the jetty meets the wharf;
- a wharf structure;
- berthing and mooring dolphins;
- ship access gangways and conveyor cross-overs and cross-unders;
- aids to navigation;
- a ship arrestor barrier structure; and
- berth pockets, departure basins, swing basins, link channels, new departure channel and tug access channel.

Construction of the project will require dredging of approximately 54 Mm^3 of material. For the purposes of the impact assessment, it has been assumed that each stage would be consecutively dredged, resulting in dredging being undertaken in 56 discontinuous months within a five to six year period, depending on the commencement of each development stage. These dredging works will be associated with the departure channel and navigational facilities, access jetty and wharf structure.

The marine loading facility will be capable of berthing and loading 250,000 dry weight tonne (DWT) vessels with a design provision for 320,000 DWT vessels to berth and load in the future. Operational activities pertinent to the marine environment impact assessment include:

- maintenance dredging of the access channel and navigational facilities;
- vessel movements with associated propeller wash and sediment disturbance;
- noise emissions generated by vessels and loading operations;
- infrastructure lighting emissions;
- loading of iron ore; and
- wastes, discharges and spills associated with vessels and infrastructure.

Further descriptions of the proposed infrastructure and subsequent operations can be found in **Chapter 2, Project Description** and **Chapter 8, Emissions, Discharges and Wastes**.

Listed in **Table 10.1** are the environmental factors and aspects identified as relevant to the marine impact assessment. A detailed impact assessment has been conducted for each of the key marine environmental factors. Although relevant to the assessment, avifauna was determined as not requiring detailed assessment or management measures beyond standard practice. As such, only a brief description of the potential impacts and proposed management measures are presented for this factor.

Table 10.1 – Marine Environmental Factors and Aspects

Factors	Section	Aspects*
Key Factor – Marine Water and Sediment Quality	10.2	Seabed disturbance (c, o) Dewatering discharge (c) Marine noise and vibration (c, o) Light spill (c, o) Physical presence (c, o) Physical interaction (c, o) Liquid and solid waste disposal (c, o) Leaks and spills (c, o)
Key Factor – Marine Habitat	10.3	
Key Factor – Marine Fauna	10.4	
Key Factor – Geomorphology and Coastal Processes	10.5	
Relevant Factor – Avifauna	10.6	

** c = construction; o = operation*

10.2 Key Factor – Marine Water and Sediment Quality

This section presents the assessment of impacts on marine water and sediment quality associated with the project, incorporating design modifications, mitigation and management measures applied to manage predicted impacts.

10.2.1 Management Objectives

The management objectives that will be applied to the project for the environmental factor of marine water and sediment quality are:

- to ensure that the environmental values and health, welfare and amenity of people and land uses are not adversely affected; and
- to meet statutory requirements and acceptable standards.

10.2.2 Description of Factor

The baseline characteristics of the marine water and sediment quality of the receiving marine environment were determined through studies collected for a period of 23 months which are described in **Chapter 6, Existing Marine Environment**. In particular, the main studies were:

- baseline water quality monitoring program (SKM 2009f, **Appendix B19**); and
- sediment quality investigations (SKM 2009e, **Appendix B6**).

Marine waters in the project area are tidally dominated by a large semi-diurnal regime, with the highest astronomical tide being 7.9 m. These large tides drive strong currents of around 1 m/s (or 2 knots), which can increase at the entrances to tidal creeks along the coastline, and are typically aligned north-west to south-east. Wind is also important to nearshore water movement, resulting in long-term drift towards the east and north-east during spring and summer months (wet season). In autumn and winter (dry season) weaker and less persistent current reversals occur.

Nearshore environments, in water depths shallower than 5 to 10 m CD, were characterised by variable turbidity, high sedimentation rates and highly variable light and temperature conditions. Much of the variability observed in marine water quality conditions is attributable to season, weather, tide and distance offshore.

The dominant sediment types were medium to coarse grain sands containing shell fragments. Sedimentation studies indicated that fine sedimentary material present in the water column, settles out. The physical environment causes fine particles to be resuspended and to accumulate on the seabed. Fine material therefore only accumulates in quiet water or depositional locations, such as in the lee of islands.

Sediments in the marine development footprint were assessed for contamination. The nearest potential sources of contaminants to sediments in the areas proposed for dredging are the existing shipping channel (1 km east) and the entrance of the Inner Harbour (approximately 5 km south-east). Results of the chemical analyses were compared with the Commonwealth Government's assessment process (see **Section 10.2.3**) to determine if there were any potential contaminants of concern present in the material proposed for dredging and disposal. Of the parameters measured, arsenic, chromium and nickel were found at some locations to be above the recommended levels at which contamination could be a concern. The lack of nearby contaminant sources makes it unlikely that sediments are contaminated due to anthropogenic activities, and rather the elevated levels are naturally occurring for these parameters in this region. Bioavailability and toxicity tests found no evidence to suggest the sediments in the areas proposed for dredging pose a risk to the environment.

10.2.3 Assessment Guidance

Guidance on the assessment of impacts to marine water and sediment quality exists at State and Commonwealth government levels. A summary of the assessment guidance documents relating to sediment and water quality utilised as a framework for this impact assessment is provided in **Table 10.2**.

Table 10.2 – Legislation and Guidance Documents Specific to Water and Sediment Quality

Document	Description
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000a)	Provides an assessment framework for protecting the uses of water through conservation of ambient water quality in aquatic environments in Australia and New Zealand.
National Ocean Disposal Guidelines for Dredge Management (Environment Australia 2002)	Provides a framework for the environmental impact assessment of sea disposal of dredged materials in Australia.
Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives (DoE 2006b)	Provides an assessment framework for the protection of fresh and marine water quality on the Pilbara region of Western Australia.
State Water Quality Management Strategy Document No. 6 (DoE 2004b)	Provides an assessment framework for the protection of fresh and marine water quality in Western Australia.
Environmental Assessment Guidelines No. 7 – Marine Dredging Proposals (EPA 2010)	Provides a spatially-based framework for the presentation and assessment of impacts on benthic communities and habitats that are predicted to arise from marine dredging in Western Australia.

10.2.3.1 Commonwealth Waters

The *National Water Quality Management Strategy* (2002) outlines the Commonwealth framework to ensure a common approach to water quality management across states and territories, as well as Commonwealth jurisdictions. The approach has been adopted by Western Australia's State government in the State Water Quality Management Strategies as detailed in **Section 10.2.3.2**. Supporting this strategy are the Marine and Fresh Water Quality Guidelines (ANZECC/ARMCANZ 2000).

National Ocean Disposal Guidelines for Dredged Material

The National Ocean Disposal Guidelines for Dredged Material (NODGDM) (Environment Australia 2002) provide guidance on assessing material proposed for ocean disposal. Included in the assessment process is the rigorous evaluation of physical and chemical characteristics of sediments within the proposed dredging footprint and in the area(s) to which the material is planned for disposal.

Recently, the NODGM have been revised and the environmental assessment process is currently guided by the National Assessment Guidelines for Dredging (Commonwealth of Australia 2009). However as the proposed Outer Harbour Development approvals for sea dumping were initiated under the NODGDM (Environment Australia 2002), it is under these guidelines that the suitability for ocean disposal of dredged materials has been assessed.

10.2.3.2 State Waters

State Water Quality Management Strategies

The *State Water Quality Management Strategy No.6* (DoE 2004b) outlines the framework for Western Australia for fresh and marine water quality, and water quality monitoring and reporting. The framework requires that all significant resources in Western Australia are spatially defined on a priority basis and that environmental values are developed for each of these resources. For each environmental value, there are environmental quality objectives and subsequent environmental quality criteria.

The *Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives* (DoE 2006b) defines key environmental values and maps with levels of ecological protection for the Pilbara region, including the Port Hedland area (**Table 10.3** and **Figure 10.1**). The EPA endorses these environmental values and levels of ecological protection as a guide for assessing environmental impacts.

Areas of high and moderate levels of ecological protection are recognised within the Port Hedland area and within the project footprint (**Figure 10.1**). Areas of high protection have been described as areas having very low levels of contaminants and where biological indicators show no detectable change from natural variation (DoE 2006b).

Table 10.3 – Environmental Values and Environmental Quality Objectives

Environmental Values	Environmental Quality Objectives
Ecosystem Health (ecological value)	Maintain ecosystem integrity This means maintaining the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems.
Recreational and Aesthetics (social use value)	Water quality is safe for recreational activities in the water (e.g. swimming). Water quality is safe for recreational activities on the water (e.g. boating). Aesthetic values of the marine environment are protected.
Cultural and Spiritual (social use value)	Cultural and spiritual values of the marine environment are protected.
Fishing and Aquaculture (social use value)	Seafood (caught or grown) is of a quality safe for eating. Water quality is suitable for aquaculture purposes.
Industrial Water Supply (social use value)	Water quality is suitable for industrial supply purposes.

Source: Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives (DoE 2006b).

The Environmental Quality Objective (EQO) for the 'maintenance of ecosystem integrity' identifies four Levels of Ecological Protection (LEP) for Pilbara coastal waters which have been developed through extensive stakeholder and community consultation (**Table 10.4**).

The State framework, and those environmental values and environmental quality objectives developed for the Pilbara coastal waters, have been taken into consideration in the assessment of potential environmental impacts as a result of the proposed Outer Harbour Development.

Figure 10.1 presents the LEP boundaries defined by the Pilbara Coastal Water Quality Consultation Outcomes document (DoE 2006b). A moderate LEP (90% ecological protection) has been applied to areas around existing wharves, jetties and ship turning basins within the Inner Harbour. Currently a high LEP has been applied to all other areas in the Port Hedland inner and outer harbour regions (DoE 2006b).

The implementation of the proposed Outer Harbour Development will require the LEP boundaries to be extended to encompass the new marine infrastructure. This will be done in accordance with:

1. Guidance on Boundary Revisions within the Pilbara Coastal Water Quality Consultation Outcomes: Environmental Outcomes and Environmental Quality Objectives (DoE 2006b); and
2 Guiding Statement within the State Water Quality Management Strategy No.6: implementation Framework for Western Australia for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Monitoring and Reporting (National Water Quality Management Strategy). Report no. SWQ6 (DoE 2004b).

A moderate LEP boundary to include the marine infrastructure of the proposed Outer Harbour Development has been indicated in **Figure 10.1**. This boundary includes an area extending out radially 250 m from the proposed infrastructure that lies within State managed marine waters.

The Draft *Environmental Assessment Guidance No 7 for Marine Dredging Proposals* (EPA 2010) has an overarching objective to provide a spatially-based assessment framework to enable the provision of clear and consistent representation of predicted impacts associated with marine dredging proposals. This framework provides guidance for the

Table 10.4 – Levels of Ecological Protection linked to the EQO for 'Maintenance of Ecosystem Integrity'

Level of Ecological Protection	Environmental Quality Condition (Limit of Acceptable Change)	
	Contaminant Concentration Indicators	Biological Indicators
Maximum	No contaminants – pristine	No detectable change from natural variation
High	Very low levels of contaminants	No detectable change from natural variation
Moderate	Elevated levels of contaminants	Moderate changes from natural variation
Low	High levels of contaminants	Large changes from natural variation

assessment, and subsequent monitoring and adaptive management of impacts to benthic communities and habitats during marine dredging activities.

The project will cause both direct and indirect impacts on benthic primary producer habitat (BPPH) from changes in water quality due to sediment suspension and settlement as a result of dredging and disposal activities. The impacts and associated loss calculations, and management and mitigation measures to BPPH due to dredging and disposal activities are discussed in **Section 10.3**.

10.2.4 Potential Impacts

Potential impacts to marine water and sediment quality resulting from aspects associated with the proposed Outer Harbour Development are discussed below and summarised in **Table 10.9**. The aspects that directly impact marine water and sediment quality are:

- water column and sea bed disturbances due to construction and maintenance dredging activities;
- physical presence of vessels;
- dewatering discharge to Salmon Creek;
- liquid and solid waste disposal during construction and operation;
- leaks and spills during construction and operation; and
- discharge of stormwater.

10.2.4.1 Water Column Disturbance due to Construction Dredging

Construction dredging for the proposed Outer Harbour Development includes the dredging of 54 Mm^3 of material to accommodate the construction of the channel and berthing facilities. Dredging has been assumed to occur in a staged approach, resulting in 56 months of dredging over a five to six year period, allowing for worst case cumulative environmental impacts. A summary of the proposed construction dredging activities, their timing and the associated volumes of material is provided in **Table 10.5**.

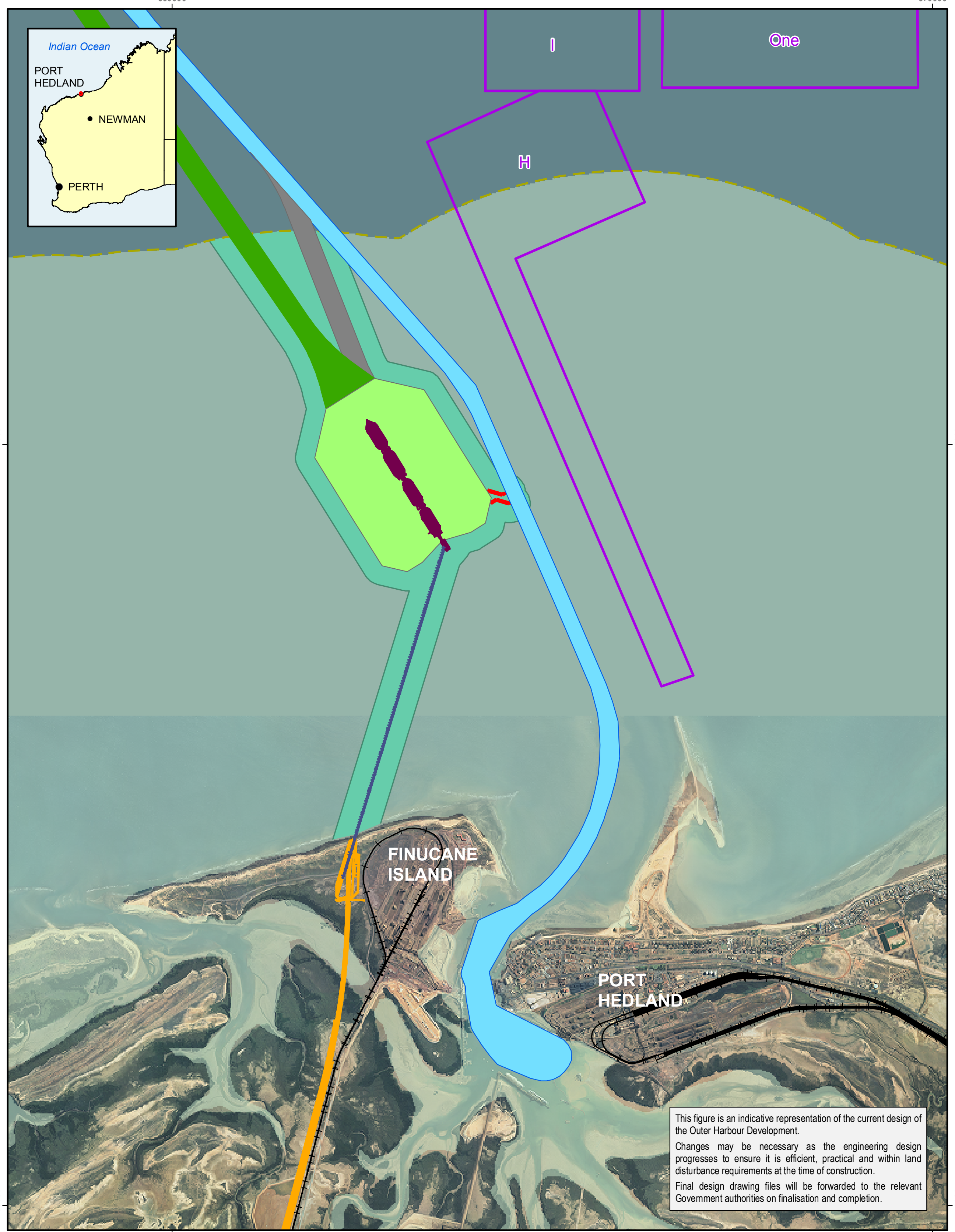
Due to the range of sediment types present, a combination of dredging methods is required. It is proposed that a trailing suction hopper dredger (TSHD) will be used for unconsolidated materials, while harder materials will first require cutting and/or crushing using a cutter suction dredger (CSD). Once consolidated material has been crushed by the CSD, the material will be left on the seabed and subsequently removed by the TSHD. In the shallower areas, the CSD will likely be initially required to dredge materials so that the water depths are sufficiently deep for the operation of the TSHD. Where this is the case, the material dredged by the CSD will be stockpiled in deeper water within the dredging footprint, from where the TSHD will remove the material once water depths are sufficient for access.

Sediment particles released into the water column (suspended solids) from dredging activities will generate a sediment plume. The extent of the plume will be determined by a range of factors including the dredging method, sediment characteristics, ambient current movement, water depth and wind direction. The net effect of sediment particles being mobilised from the dredging will be an increase in total suspended solid (TSS) concentrations in the water column. In addition, the higher load of sediment particles in the water column will cause a higher amount of sediment to deposit out of the water column resulting in increased sedimentation rates. Particle drop out is governed by the hydrodynamics and the sediment particle size. In areas with high 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.

Modelling of the impacts (as indicated by TSS and sedimentation) from the sediment plume generated by the proposed dredging and spoil disposal activities, was undertaken by Asia Pacific ASA (APASA) and is included in **Appendix B4**. A summary of the modelling approach, objectives and findings is

Table 10.5 – Construction Dredging Activities, Indicative 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



Legend

Ecological Protection Level
- Moderate Protection
- 99% Habitat Protection
- State/Commonwealth Jurisdiction Boundary
- Proposed Departure Channel
- Proposed Berth Pockets and Swing Basins
- Proposed Link Channel
- Existing Shipping Channel
- Proposed Tug Access Channel
- Proposed Jetty
- Proposed Wharf
- Existing Railway
- Spoil Ground (Existing)
- Proposed Infrastructure Corridor

0 0.5 1 2
kilometres
Scale @ A4: 1:65,000
Datum: GDA94
Map Grid: MGA94 Zone 50

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Source:
Orthorectified Aerial Photograph: 06/2010 (BHPBIO)
Topography: GA, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)
Spoil Grounds: 1210-C-00287 (19/08/2008)

Figure 10.1 Levels of Ecological Protection Identified for the Proposed Outer Harbour Development

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provided below. In addition, 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 **Appendix B4**.

Modelling Approach

Modelling of the sediment plume likely to be generated by construction dredging and disposal activities 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 resulting from dredging operations given the prevailing current and wave conditions. For further detail on the sediment transport model refer to Section 8 of **Appendix B4**.

The model HYDROMAP described the flow-field conditions that are locally induced in the Port Hedland coastal region where tides and winds are the most important hydrodynamic forces. Validation demonstrated that HYDROMAP accurately 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, which is 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 activities. Validation of the SWAN model demonstrated accurate reproduction of observed wave parameters across the full wave spectra.

The modelling domain[1], spanning 131 km from east to west and 83 km from north to south was sufficiently large to encompass the total area that may be affected by sediment plumes generated by the dredging and disposal activities. This area also encompassed the modelled cumulative impacts due to resuspension of particles distant from the project activities.

Bathymetric data used to define the three dimensional shape of the seabed in the model were obtained from multiple sources. LiDAR[2] survey data was used for near shore areas. In very shallow areas where LiDAR did not cover the full area, information was augmented by a bathymetric interpolation produced by GeoScience Australia. Aerial imagery was also used to define the bathymetry in areas where the interpolated bathymetry was considered inadequate. Astronomical tides were included on all open boundaries of the model, by spatial interpolation of the tidal constituent data (amplitude and phase).

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

Data used to drive the models included:

- detailed bathymetric data derived from the LiDAR[2] 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 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 dredgers, predicted dredge logs (i.e. when, where and for how long a dredger will operate) and disposal of the dredge spoil.

Modelling Assumptions and Limitations

Assumptions and limitations of the modelling outputs included:

- the model computes the TSS concentration above background[3] levels that result 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 over estimate TSS concentrations through material being repeatedly resuspended.

1 The modelling domain is the spatial extent represented by the predictive models.

2 LiDAR stands for light detection and ranging. It is a technique used to construct an image representing the terrain of an area by firing rapid pulses of light at the landscape and a sensor measures the return of light once it bounces off the landscape surface. The time taken for the light to return to the sensor allows distances and therefore topography to be measured (http://www.csiro.au/resources/LightDetectionLidar.html).

3 Background is a reference to natural conditions of the existing environment (refer to **Section 6.4**).

A useful measure for calculating the amount of sediments ejected into the water column during dredging is the resuspension rate, which is calculated as the proportion of the production rate – or dredging rate – that is discharged to the water column. The production rate is the amount of sediment removed over time and published suspension rates from TSHD operations, including overflow, range from 0.003% to 2% of the production rate[4] (Anchor Environmental 2003). As a conservative approach, a rate of 1% was applied to this study for the overflow phase, and 0.03% for dredging with no overflow.

Model output parameters were selected to generate near seabed predictions (0.5 to 1.5 m above bottom) for TSS concentrations. It is these concentrations which are most applicable to the impacts of the sediment plume on benthic primary producers and their habitats (refer **Section 10.3**). The modelling results predict that the extent and severity of the sediment plume is greatest just above the seabed. As such, the magnitude of impact predictions made for the proposed Outer Harbour Development 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 appropriate 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.

Although background TSS was not included in the model results, it was taken into account in the seasonal threshold values used to assess impacts on benthic primary producers and their habitats, which is discussed in **Section 10.3**. The model predicted that during the dredging program the amount of fine sediment available as a source for resuspension, continually increased such that a sediment plume appeared away from the immediate dredging and disposal areas.

Modelled Scenarios

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

Initial modelling investigations were undertaken to test and compare the influence of location on spoil disposal. 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.

Initially, 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.

Simulation scenarios were separated into four dredging operations:

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.

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 conservative.

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 tides 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 subjected to the prevailing waves, with a more irregular frequency.

4 The 80th percentile of this range is 1% (Anchor Environmental 2003).

The modelling demonstrated that dredging and spoil disposal activities will create a sediment plume characterised by increased TSS 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. Close to the seabed, the plume will be much larger in area and will be subject to regular resuspension of sediment (**Figure 10.2**). The areas in which the sediment plume is present will shift seasonally primarily due to changing conditions in the wave climate. The presence of the plume will persist throughout construction dredging activities, gradually dissipating following their completion.

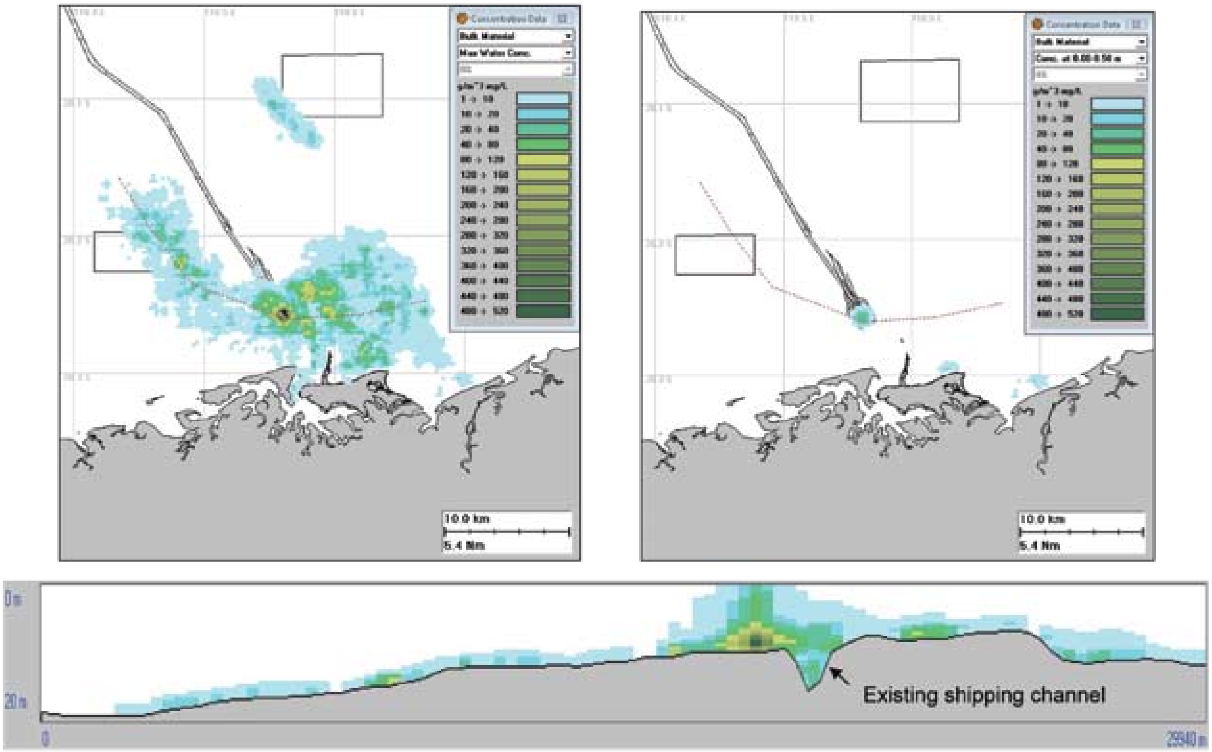

Figure 10.2 – Sediment Plume Predictions as TSS Concentrations (in mg/L) at the Surface (top left), 0.5 m above the Seabed (top right) and a Benthic Profile (bottom)

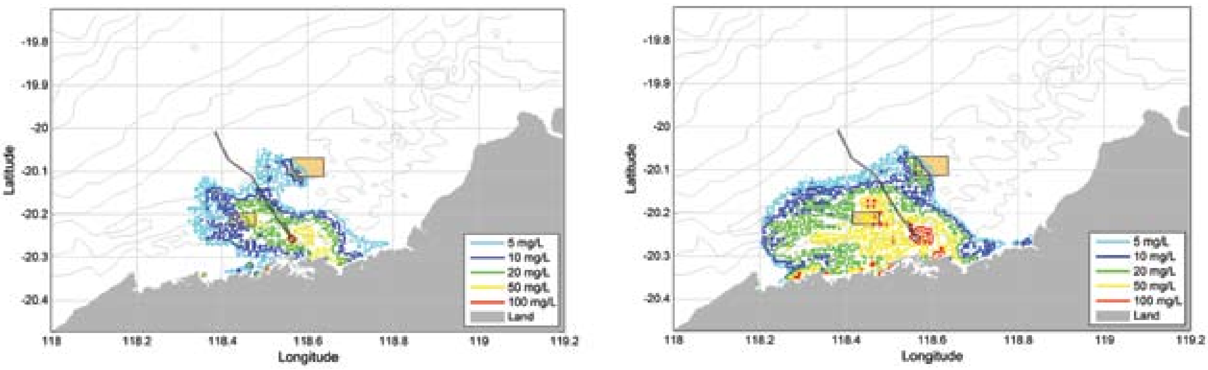

Figure 10.3 – Stage 1 February to April (left) and October to December (right) of Year 1; 80th Percentile TSS Concentrations (in mg/L)

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 will result in a directional change of the plume. A net migration of sediment to the west will occur by the middle of the dry season, while during the wet season the plume is advected in an east and north-east direction (**Figure 10.4**).

At the height of the wet season the plumes will move in a north-easterly direction. 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 is 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 reduces, followed by a transitional period and re-establishment 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. Such TSS concentrations are highly localised, forming 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 shifts further offshore because dredging during this stage includes the outer part of the channel (**Figure 10.5**).

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 however of the sediment plume is predicted to be very similar to that predicted for previous stages, with westward migration in the dry season (**Figure 10.6**), and north-easterly migration in the wet season (**Figure 10.7**).

Modelling Results – Changes to Sedimentation Rates

Modelling of sediment deposition indicates that the majority of the sediment is predicted to sink within a short distance from the construction dredging and disposal activities. However, with increasing inputs and spreading of the sediment particles, predicted deposits extend progressively further away from these areas (**Figure 10.8**).

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 10.9**). Although the wet season conditions are responsible for the greatest spread of increased sedimentation rates, the spatial extent of increased sedimentation greater than 0.1 kg/m^2 is notably smaller in comparison to the spread of increased TSS predictions.

Although the predictions for sediment deposition over time indicate a progressive build up of sediment particles, this trend was not always consistent in the longer term. Periods of highly energetic hydrodynamic conditions that created the most extensive sediment plumes, as indicated by TSS concentrations, showed a far smaller plume distribution as indicated by sedimentation, as much of the fine sediments either remained suspended during this period or were resuspended. This resulted in a time lag between the worst TSS plume conditions occurring, caused by particles resuspended in the water column, and the worst sedimentation conditions caused by less energetic conditions allowing sediment particles to settle out of the water column (**Figure 10.10**).

Areas of increased sedimentation were 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 10.11**, 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.

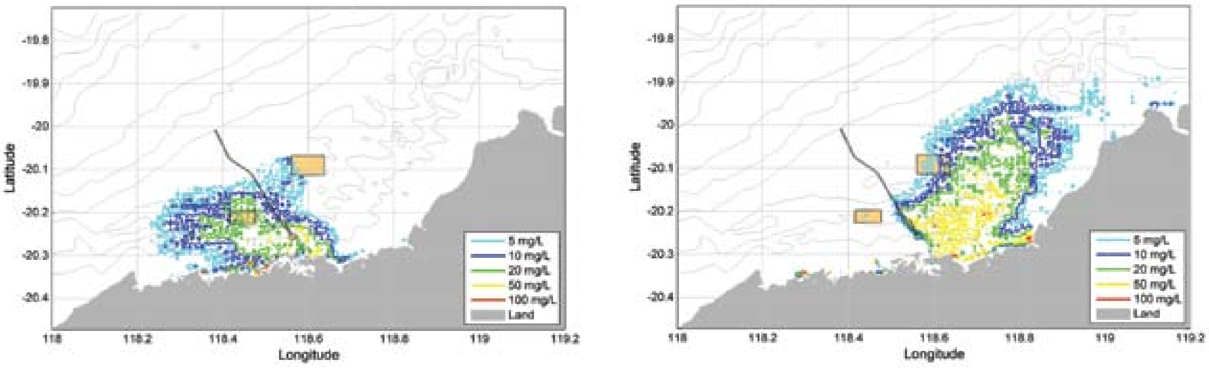

Figure 10.4 –Stage 1 Dry Season (left) and Wet Season (right); 50th Percentile TSS Concentrations (in mg/L)

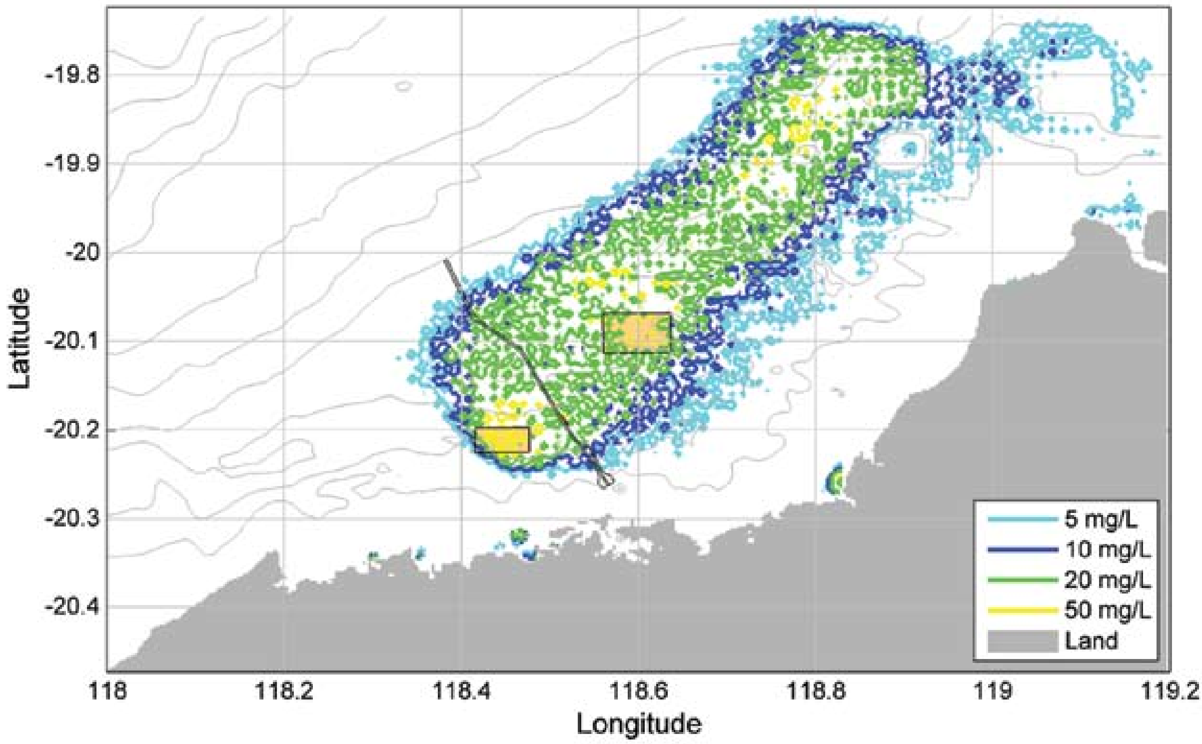

Figure 10.5 – Stage 2 December to March of Year 4; 80th Percentile TSS Concentrations (in mg/L)

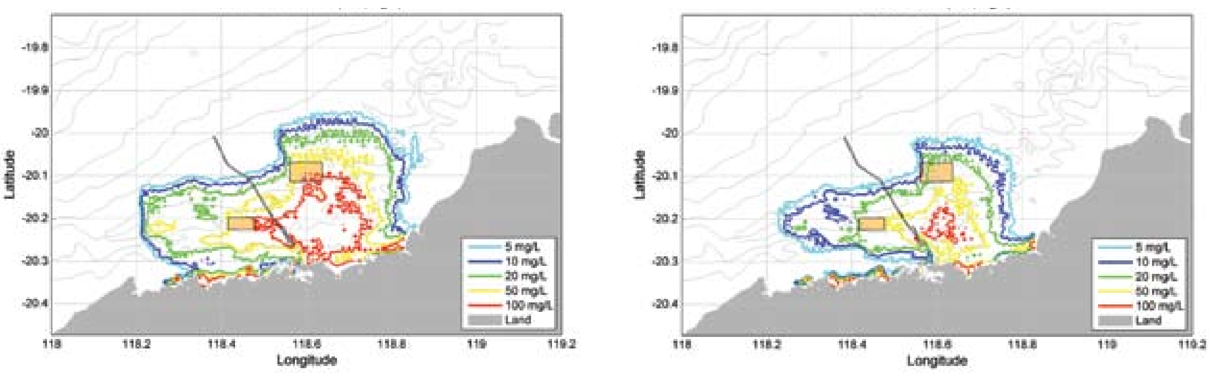

Figure 10.6 – Dry Season: Stage 3 September to November of Year 5; 80th Percentile (left) and 50th (right) TSS Concentrations (in mg/L)

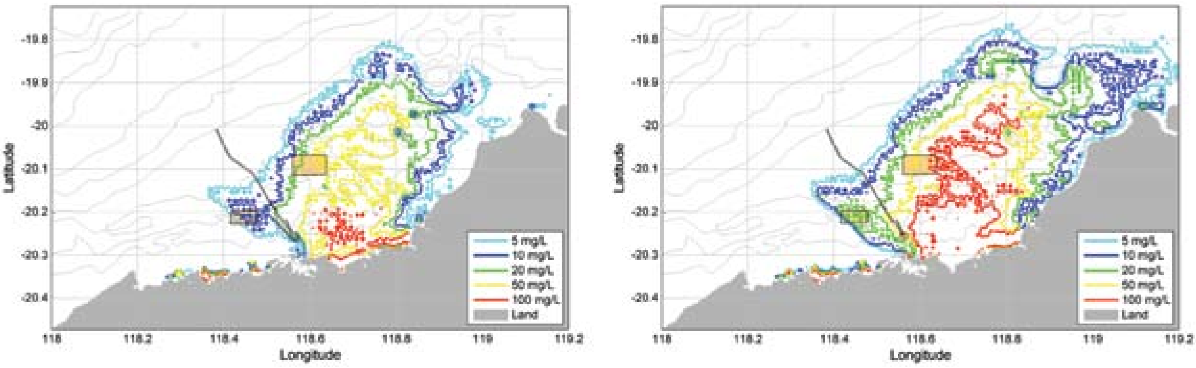

Figure 10.7 – Wet Season: Stage 3 November to December of Year 5; 80th Percentile (left) and 50th (right) TSS Concentrations (in mg/L)

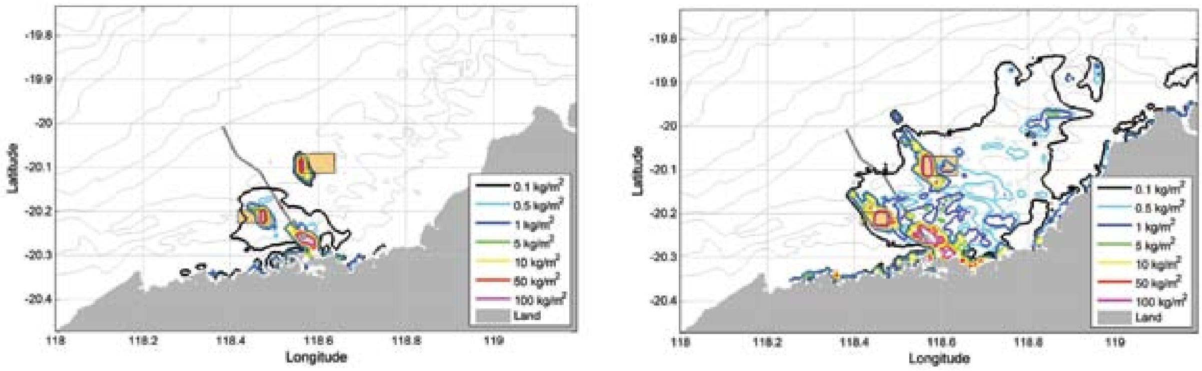

Figure 10.8 – Stage 1: 2 to 4 Months after Commencement (left) and 10 to 12 Months Later (right); 80th Percentile Sedimentation Rates (in kg/m²)

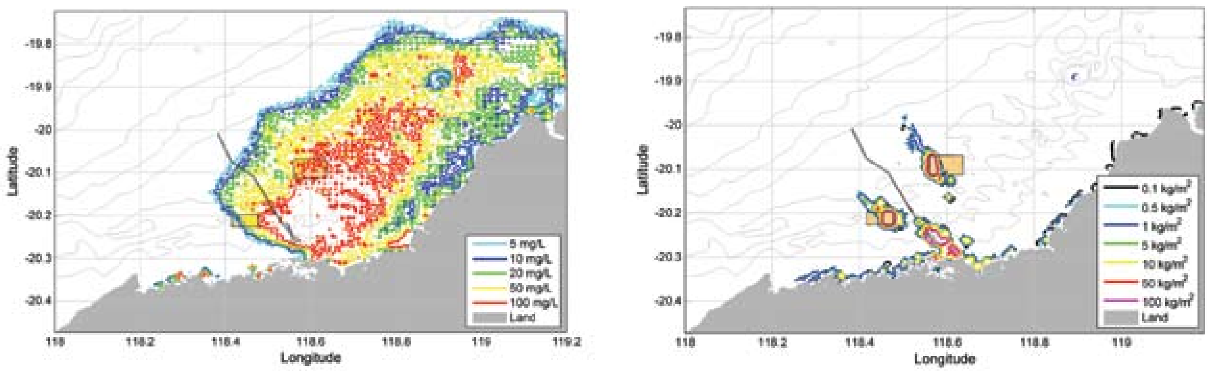

Figure 10.9 – Wet Season: Stage 1 December to January 80th Percentile TSS Concentrations (in mg/L; left) and Sedimentation Rates (in kg/m²; right)

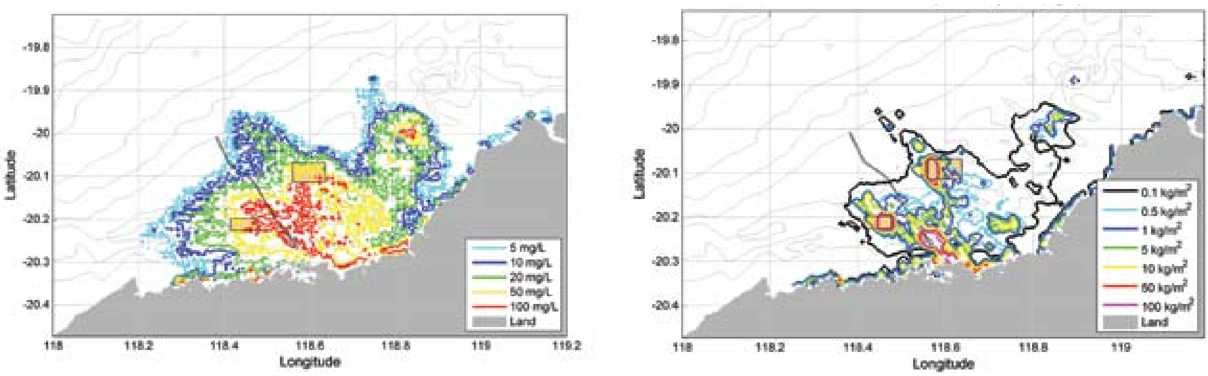

Figure 10.10 – Wet to Dry Transition: Stage 1 April to June 80th Percentile TSS Concentrations (in mg/L; left) and Sedimentation Rates (in kg/m^2; right)

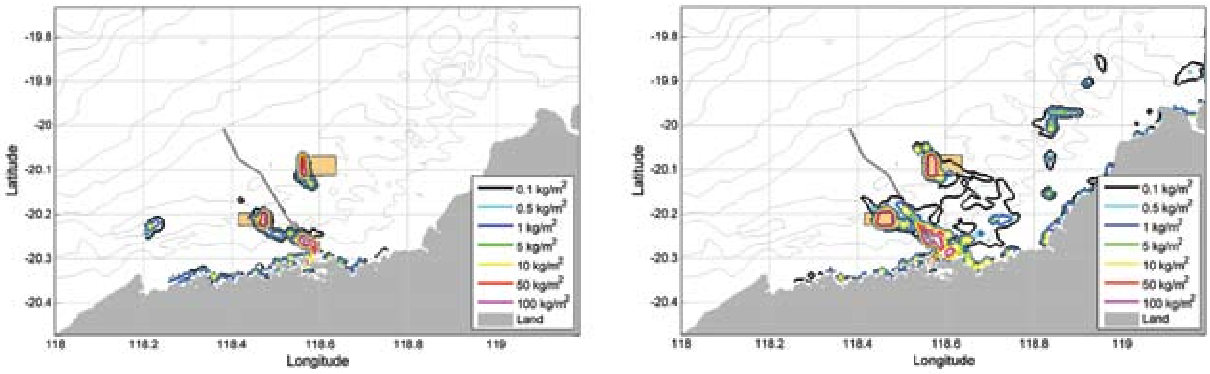

Figure 10.11 – Stage 1 June to August (left) and Stage 2 February to April (right) 50th Percentile Sedimentation Rates (in kg/m^2)

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 is 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 were predicted to establish sufficient shear stress[5] 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 been deposited. Resuspension of finer sediment particles was also predicted in modelling simulations to generate secondary surface plumes and contribute to sedimentation rates along the shallow coastal margin.

Modelling Results – Spoil Disposal Areas

The areas of the proposed Outer Harbour Development identified for spoil disposal lie in what is described as a dispersive environment, meaning that sediment particles are naturally susceptible to resuspension and will be moved away over time.

To take this into account, relatively short period (30 days) model simulations of spoil disposal into Spoil Grounds 3, 7 and 9 were conducted. The simulations indicated that there would tend to be a migration of finer sediment particles (clays and silts) outside the bounds of the disposal areas. This is initially due to migration with the tide as these particles tend to be jetted into the water column after the descending plume generated by ocean disposal strikes the seabed. Habitats up to 10 to 15 km to the northwest and southeast of the disposal grounds were predicted to receive elevated TSS concentrations in the water column, and subsequently increased sedimentation. A greater net drift of spoil material was indicated for disposal into areas closer to shore than areas further offshore, indicating a response to the onshore steering of tidal currents with proximity to land (**Figure 10.12** and **Figure 10.13**).

5 Shear Stress is a measure of the force of friction from a fluid acting on a body in the path of that fluid. In the case of open water flow, it is the force of moving water against the sea bed.

Over the longer term, the modelling predicted that material deposited in the disposal areas, which are located in water depths sufficiently shallow for storm swells to penetrate to the seabed, will disturb the heavier sediment particles resulting in trapped fines being resuspended. Given that this circumstance is related to storm events, resuspension of fines from disposal areas is likely to continue for several years after completion of construction disposal.

Summary of Predicted Impacts

Modelling of the construction dredging and disposal activities of the proposed Outer Harbour Development predicted that heavier sediment particles and a proportion of finer sediments will deposit around the dredging and disposal operations while finer sediments will deposit in 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 to the seabed (0.5 to 1.5 m 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 northeast in summer months and west in winter months is predicted.

Evaluation of sediment plume behaviour associated with dredge spoil disposal predicted a greater net drift of spoil material into areas up to 10 to 15 km closer to shore from disposal area boundaries. This is in response to the onshore steering of tidal currents with proximity to land. In addition, heavier sediment particles will be distributed during storm events in disposal areas located in shallower waters, resulting in trapped fines being resuspended. This will likely occur for several years after completion of construction disposal, and will be a function of the frequency of local storm events.

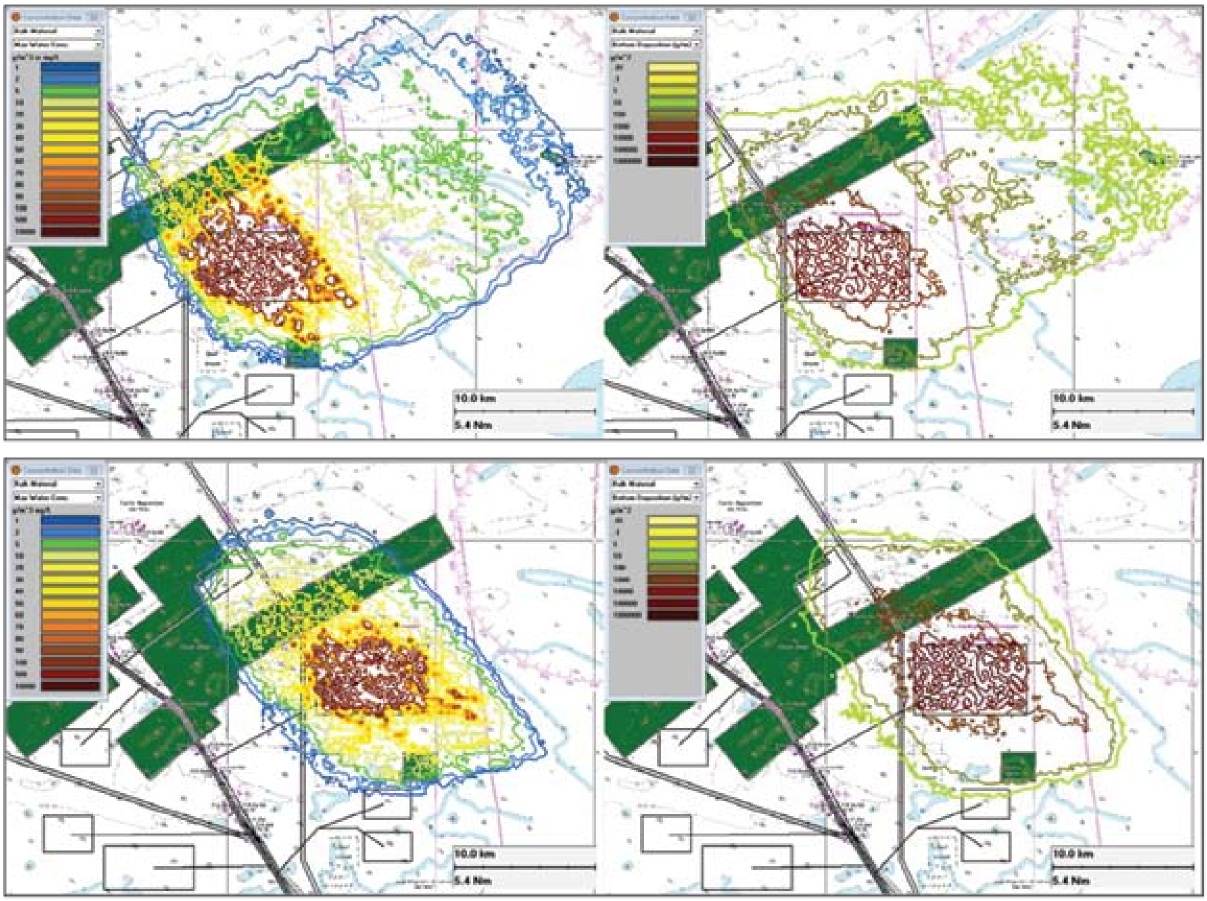

Figure 10.12 – Estimates of Highest TSS concentrations (in mg/L) and Highest Sedimentation (in g/m²) from Disposal into Spoil Ground 3 in January (left) and May (right)

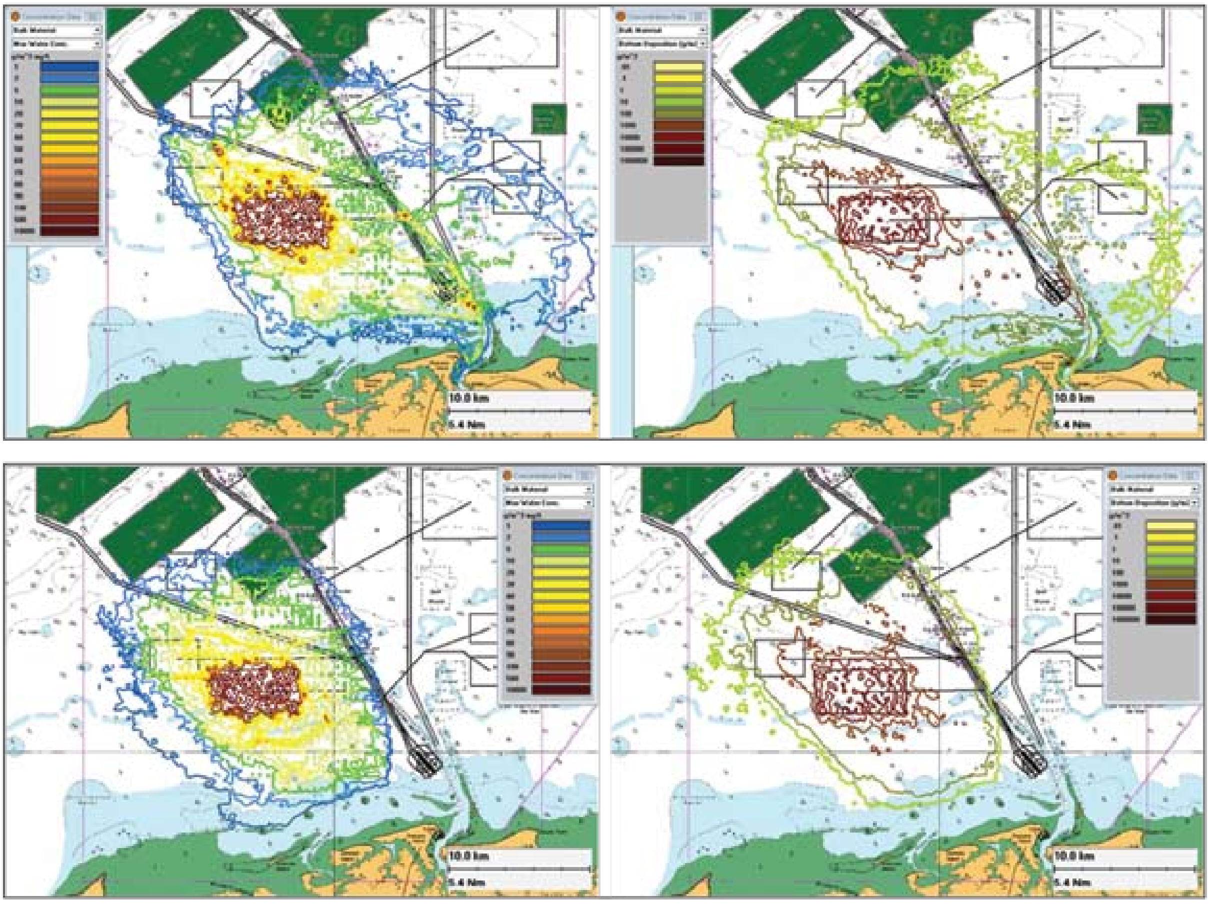

Figure 10.13 – Estimates of Highest TSS concentrations (in mg/L) and Highest Sedimentation (in g/m²) from Disposal into Spoil Ground 7 in January (left) and May (right)

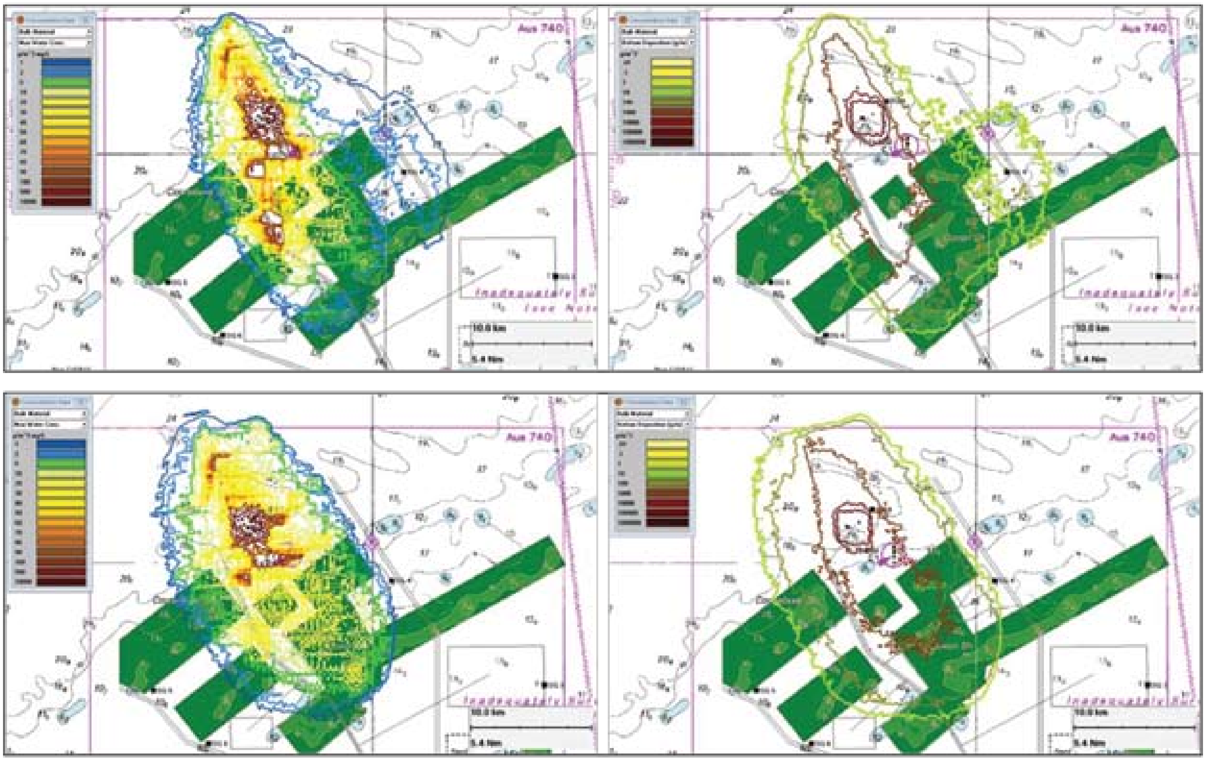

Figure 10.14 – Estimates of Highest TSS concentrations (in mg/L) and Highest Sedimentation (in g/m²) from Disposal into Spoil Ground 9 in January (left) and May (right)

10.2.4.2 Sea Bed Disturbance due to Ocean Disposal of Construction Dredging Spoil Disposal

Dredge spoil will be potentially disposed of at four spoil grounds, Spoil Ground 2, 3, 7 and 9. The indicative volumes of spoil considered in the modelling (APASA 2009) is summarised in **Table 10.6**.

Table 10.6 – Volume of Dredge Spoil to be Disposed of at each Spoil Disposal Ground utilised for the Modelling

Ground*	Surface Area (ha)	Volume (Mm^3)
Spoil Ground 2	1,093	None (contingency)
Spoil Ground 3	2,400	27
Spoil Ground 7	2,000	25.75
Spoil Ground 9	700	1.25

* Please note that Spoil Ground 2 is proposed as a contingency ground only.

The dredge modelling was undertaken on the basis that half the material to be dredged from the berth pockets, swing basin and departure channel will be disposed of into Spoil Ground 3 over the 2,400 ha area of this ground. The vast majority of the remaining dredged material will be disposed of at Spoil Ground 7. The footprint of Spoil Ground 7 is 2,000 ha. Finally, some of the material to be dredged from the outer portion of the shipping channel was modelled assuming disposal at Spoil Ground 9 (which, similar to Spoil Ground 2, is proposed as a contingency). Spoil Ground 9 is 700 ha in area while Spoil Ground 2 is 1,093 ha in area.

Potential spoil grounds were chosen based on sufficient size and water depth to accommodate the proposed volume of material. The proposed disposal areas are largely devoid of benthic habitat while still being within a reasonable sailing distance of the dredging activities. The preferred disposal locations comprise benthic habitat of vast sandy areas that lie between limestone ridgeline features. Further detail on spoil ground selection is included in SKM (2009h).

10.2.4.3 Sediment Quality Impact Assessment

Disposal of dredged material for sea dumping is governed by the Commonwealth *Environment Protection (Sea Dumping) Act 1981* which is under the jurisdiction of the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC, previously Department of Environment, Water, Heritage and the Arts (DEWHA)). The suitability of the dredged material for unconfined ocean disposal for the proposed Outer Harbour Development was determined in accordance with the National Ocean Disposal Guidelines for Dredged Material (NODGDM) (Environment Australia 2002).

Likely contaminants of concern were identified based on a regional assessment. Appropriate sampling and subsequent analysis were undertaken to test for the potential contaminants to determine suitability of material for unconfined ocean disposal.

A summary of the key findings includes:

- Sediment throughout all footprint and potential spoil ground areas was characterised as medium to coarse grained, with less than or equal to 10% of material in any area being under 100 µm in diameter.
- Arsenic (95% upper confidence limit (UCL)) was found at 30.4 mg/kg which is above the NODGDM screening level (20 mg/kg) but below the NODGDM maximum level (70 mg/kg) in surficial material in all areas investigated. The exception was Spoil Ground 7 which had slightly higher levels than the NODGDM maximum level (70.1 mg/kg). Arsenic was also found in boreholes in undisturbed seabed base material up to a maximum depth of 4 m at 32.6 mg/kg which exceeded the NODGDM screening level but was below the maximum level, as was found in surficial sediment samples. Arsenic is believed to be a naturally occurring element in the sediments and base material of the region (DEC 2006b). It can be seen that the material sampled contained arsenic at levels above the NODGDM screening levels but were comparable to background levels indicating that the material was of natural origin. Accordingly, no further testing was required.
- Chromium (95% UCL) was found at 45.5 mg/kg which did not exceed the NODGDM screening level (80 mg/kg) to a depth of 19 m in boreholes, but was not elevated in surficial material. Chromium is likely to be a naturally occurring element in the base material of the region and subsequent testing indicated that it was neither bioavailable nor toxic.
- Nickel (95% UCL) was found at 24.2 mg/kg which exceeded the NODGDM maximum level (52 mg/kg) to a depth of 19 m in boreholes, but not in surficial material. Nickel is likely to be a naturally occurring element in the base material of the region (DEC 2006b) and subsequent testing indicated that it was neither bioavailable nor toxic.
- Tributyltin was below analytical detection levels in all samples (less than 0.5 µg Sn/kg) and thus did not exceed the NODGDM screening level (5 µg Sn/kg) in any surficial samples or borehole samples, including the dredging area and potential spoil ground sites.

- Organic compounds (Polychlorinated biphenyls, Polycyclic Aromatic Hydrocarbons and Organochlorine Pesticides) were found to be below analytical detection in all samples tested.

From this investigation it was concluded that the material within the proposed dredging footprint is considered to be clean of contaminants and suitable for unconfined ocean disposal at designated spoil grounds (SKM 2009g, SKM 2009i) (**Appendix B6** and **B12**).

Although arsenic and chromium were detected in the sediments sampled, the presence of these parameters is believed to be naturally occurring in the sediments of this region (DEC 2006b). Arsenic and chromium were also found in samples collected from sites located at 'background' areas and in boreholes of undisturbed base material (sediments at depth). As such, the presence of these metals is not considered to be contamination due to anthropogenic activities, but rather a naturally occurring attribute of this region.

Summary of Predicted Impacts

The NODGDM (Environment Australia 2002) consider that the material to be dredged and disposed at sea is clean if potential contaminants of concern are below screening levels, or for naturally occurring materials, concentrations should not be more than twice the background level of the receiving environment (i.e. the spoil grounds). Investigations of the arsenic and chromium detected in sediment samples found the metals to be in a form that was non-bioavailable and non-toxic meaning that the metals are bound and unlikely to be released into the water column during dredging and ocean disposal. In conclusion, these metals are not considered to pose a risk to the environment during unconfined ocean disposal.

10.2.4.4 Water Column and Seabed Disturbances due to Maintenance Dredging

Periodic maintenance dredging will be required to ensure navigational features of the proposed Outer Harbour Development provide safe passage for the intended shipping traffic.

Based on historic rates of maintenance dredging at Port Hedland Port Authority shipping channel, the sedimentation rate for the proposed channel has been estimated in the range of 130,000 to 165,000 m^3 per annum. Sedimentation occurs mainly under spring tidal conditions, with the greatest rates likely to occur during tidal peaks in March and September. The effect of tropical cyclones has generally been small, with the exception of Tropical Cyclone Joan in 1975, which was estimated to cause sedimentation in the order of 350,000 m^3 for the shipping channel and harbour basin.

Modelling of sedimentation for an 'undisturbed' channel, without allowance for local seabed features, gives an estimated sedimentation rate of 430,000 m^3 per annum, which includes sediment supplied from either side, from 3 km to the offshore limit of the dredged channel, and assuming that the sidecast ridge[6] has no effect on the transport rate. To provide a balance with the observed rate of sediment accumulation within the channel, a 50% loss of supply from winnowing and a total cut-off of supply across the emergent part of the sidecast ridge have been assumed. With these assumptions, the sedimentation rate for the PHPA channel has been modelled as 195,000 m^3 per annum, which approximately corresponds to the target (maximum) rate for maintenance of facilities.

Given that maintenance dredging of existing marine facilities at Port Hedland inner and outer harbour environments occurs every three to four years, it is unlikely that maintenance dredging for the proposed Outer Harbour Development will be required more frequently than every three years. With this frequency of maintenance dredging, the proposed Outer Harbour Development will generate approximately 1.6 Mm^3 of dredge spoil over 25 years of operation. It should be noted that additional sediment could be resuspended due to the capital dredging. This factor together with the addition of a second shipping channel, in which sediment could deposit, may increase the required frequency of maintenance dredging in the future.

As with construction dredging activities, the likely impacts to marine water and sediment quality due to maintenance dredging will be the release of suspended sediments into the water column, resulting in increased total suspended solid concentrations, sedimentation rates, and decreased light penetration through the water column. In addition, release of bioavailable contaminants within the dredged material may occur during disposal. An important difference however, is that the volumes of material to be dredged during maintenance campaigns, and the duration of dredging, will be much less than that for proposed construction dredging activities.

An impact assessment for the marine environment will be prepared under the requirements of the relevant government assessment guidance on each occasion that maintenance dredging of the proposed Outer Harbour Development is required. This will ensure that environmental risks of maintenance dredging activities have been appropriately assessed and that current best management practices are applied.

6 Sidecast ridge is the name given to a ridge that runs along the edge of the existing channel where dredged material excavated during construction of this channel was sidecast directly to its edges where it has consolidated and remains as a bathymetric feature today.

Summary of Predicted Impacts

Maintenance dredging is required to ensure safe and navigable waters within the proposed Outer Harbour Development marine area. It is estimated that the proposed Outer Harbour Development will generate approximately 1.6 Mm^3 of dredge spoil over 25 years of operation.

Disturbances to marine water and sediment quality due to maintenance dredging will be infrequent and highly localised. To ensure thorough environmental impact assessment is undertaken for maintenance dredging and that best management practices are applied, regulatory approval for maintenance dredging activities will be applied for on an as needs basis.

10.2.4.5 Physical Presence of Vessels

Approximately 40 to 50 marine vessels, including supply boats, tugs, barges and other marine craft that transport supplies, materials, equipment, consumables and personnel, will be engaged during construction of the marine infrastructure.

Once completed, the proposed Outer Harbour Development facilities will deliver ore to ships via four shiploaders, each with a dedicated conveyor. Vessels with a capacity of 250,000 DWT will be used, although the final design will provide for loading 320,000 DWT.

Potential impacts arising from vessel movements in the proposed Outer Harbour Development area may be due to physical processes or contamination. Both are considered below.

Physical Processes

Movement of vessels, particularly large vessels such as ships or tugs, will create substantial disturbances in the water column due to propeller wash which in turn may resuspend underlying sediments leading to increased water column turbidity and decreased light penetration.

Disturbance of marine sediments and water quality due to vessel activity will be primarily associated with the arrival and departure of sizeable vessels. Although vessel activity will be frequent (proposed to be a minimum of two ore carriers per day), the primary areas where water and sediment quality may be affected will be the shipping channel and in the vicinity of the wharf at which the vessels will be berthing and loading.

As such, although marine sediments will likely be disturbed and subsequent quality changes to marine waters will result, the impacts will be highly localised to the wharf area, and short-term events associated with the activity of large vessels.

Contamination

Potential contamination arising from vessel activity includes biological contamination associated with the discharge of ballast waters and chemical contamination due to leaching of anti-foulant coating on the hull of vessels. The unmanaged discharge of ballast waters creates a risk of the establishment of marine species in the region, while the leaching of anti-foulant coating from vessels can interrupt life cycle stages or physiological processes of marine organisms.

Summary of Predicted Impacts

Potential impacts arising from vessel movements in the proposed Outer Harbour Development area may be due to physical processes, including disturbances in the water column due to propeller wash, or contamination due to discharge of ballast waters and leaching of anti-foulant coating.

10.2.4.9 Dewatering Discharge to Salmon Creek

In order to excavate and construct infrastructure and facilities for the five car dumpers at Boodarie, BHP Billiton Iron Ore proposes to dewater groundwater at Boodarie and subsequently discharge the water into Salmon Creek. Dewatering will occur continuously for a period of approximately 9 to 12 months for each car dumper with up to a 12 month break between each dumper excavation. During the first 12 months up to 7 ML/day of abstracted groundwater will be piped overland to Salmon Creek and discharged (**Figure 10.16**).

Impacts to the marine environment of Salmon Creek may arise due to bioavailable contaminants present within the dewatering discharge and scouring of the benthic habitat in the receiving environment leading to the possible loss of marine habitats.

Bioavailable Contaminants

Groundwater samples from 26 boreholes located at the proposed Boodarie car dumper area were collected on four occasions from July 2009 to April 2010. The water chemistry of collected groundwater samples was analysed and a summary of the results is provided in **Table 10.7**.

Laboratory results of groundwater chemistry analyses indicate that concentrations of contaminants in the groundwater are above the recommended 99% species protection trigger values (ANZECC/ARMCANZ 2000) for marine waters. However, Salmon Creek experiences considerable flushing associated with large semi-diurnal tides and this flushing action will result in a substantial dilution of contaminants within discharged dewatering water within the initial zone of mixing in the receiving environment.

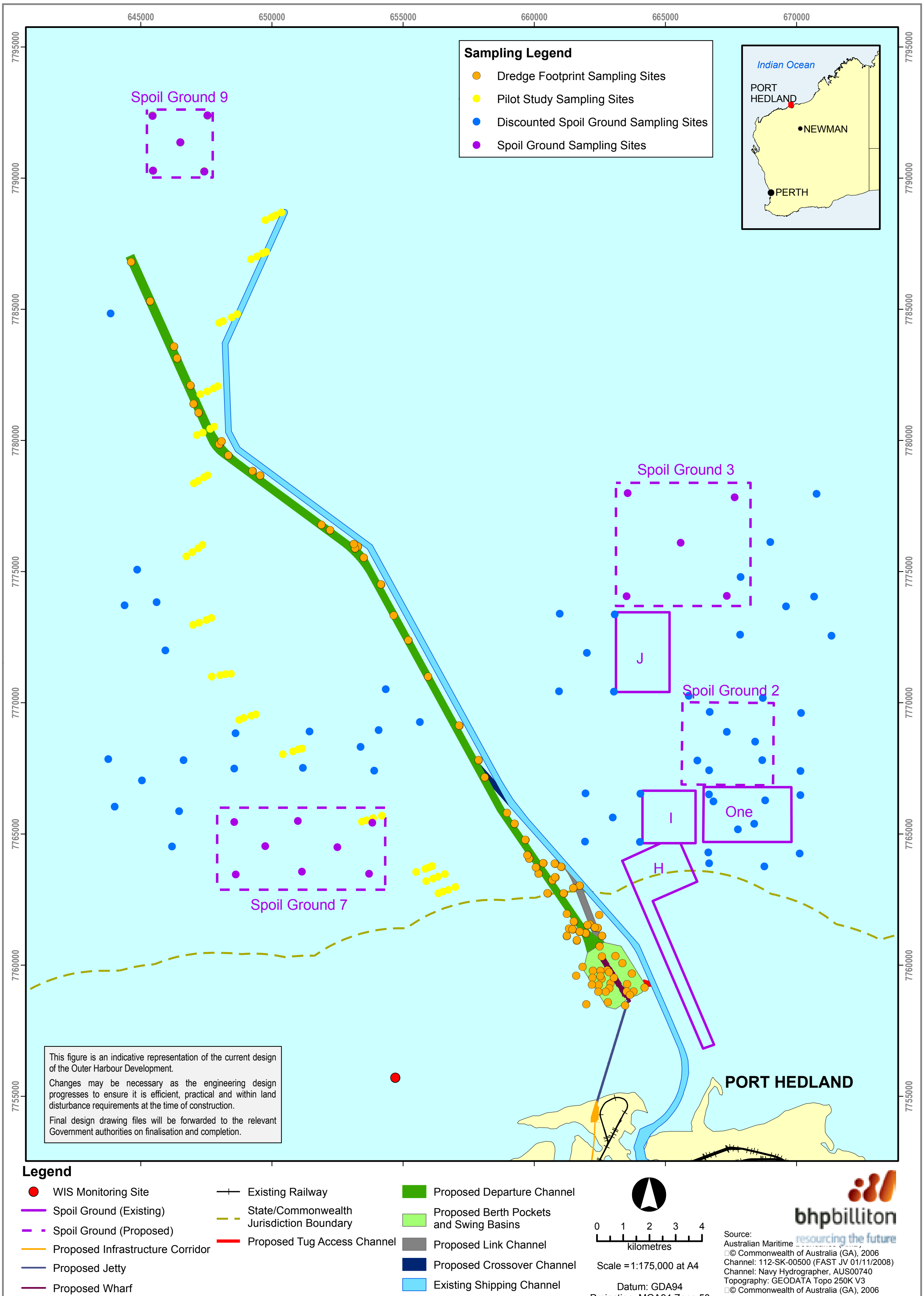

Figure 10.15 Location of Sediment Sampling Sites and Spoil Grounds

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At a minimum, a 1:10 dilution factor is expected in the initial mixing zone however this is likely to be highly conservative; therefore a 1:50 dilution factor for the initial mixing zone has also been considered. At a 1:10 dilution factor, the concentration of mercury would be slightly higher (0.12 µg/L) than the proposed trigger value (0.1 µg/L), while at a 1:50 initial dilution factor the concentration of mercury beyond the initial mixing zone (0.025 µg/L) would meet the proposed trigger value. Similarly, the concentration of zinc would be higher (16.7 µg/L) than the proposed trigger value (7.0 µg/L) at the edge of an initial mixing zone with a 1:10 dilution factor, yet, when considering a 1:50 dilution factor, the concentration of zinc beyond the initial mixing zone (3.34 µg/L) would meet the proposed trigger value.

Therefore, although water quality disturbances are likely to result from discharge of dewatered groundwater in Salmon Creek, the disturbances will be restricted to the initial zone of mixing. Contaminant concentrations in receiving waters will be rapidly diluted due to tidal flushing, thereby meeting the recommended 99% species protection limits for marine waters applicable to this waterway. Also due to the strong tidal influence and associated flushing, bioavailable contaminants that may become associated with particulate material within the receiving environment are likely to be transported rapidly from the initial zone of mixing, greatly reducing the likelihood of contaminant build up either in the water column or in the sea bed.

Of the physical parameters measured from the 11 bores at Boodarie (conductivity, pH, dissolved oxygen, temperature and turbidity) only conductivity and dissolved oxygen had extreme ranges in readings (**Table 10.8**). Conductivity ranged from fresh (1.1 mS/cm in Bore 2) to hypersaline (76.4 mS/cm in Bore 6) while dissolved oxygen ranged from nearly deoxygenated (4% at Bore 9) to 82% at Bore 1. The turbidity range was also quite high from 0.7 NTU (Bore 4) to 16 NTU (Bore 11), although the range that Salmon Creek naturally encounters was much higher. The temperature of each bore was in the low thirties (25 at Bore 9 and 27.3 °C at Bore 3was the exceptions) and pH was slightly acidic to neutral (6.1 to 7.4 pH units).

Physical Impacts

The discharge location will experience periods of low tide in which sediments on the creek floor will be directly exposed to the discharge waters. However this will last only a few hours during a tidal cycle. The area receiving direct discharge will be scoured by the force of the discharge water, but the area of disturbance is predicted to be small (less than 10 m^2) and sediment will be returned with the next tidal cycle.

The sea bed of the wide channels of tidal creeks in the Port Hedland area are typically comprised of coarse sand and gravel due to the shear stress caused by strong tides removing finer material. As a result, any additional scouring attributable to the discharge is unlikely to be extensive.

As such, although there may be scouring of the benthic environment near the discharge point the area affected will be localised (an area less than 10 m^2) and will likely be restricted to short periods when the tide is turning. In addition, rock armouring around the pipe will provide a degree of protection to the substrate.

10.2.4.7 Leaks and Spills during Construction and Operation

Spillage, leaks or disposal of fuels, chemicals, materials or waste materials has the potential to enter the marine environment and deteriorate water and/or sediment quality.

Potential sources include:

- diesel leaks or spills associated with vessel movements due to accidental discharge or collision, or deck drain discharge;
- conveyors and load-out facilities that may lose iron ore material *en route* or from ship loading during operation of the proposed Outer Harbour Development facilities.

The majority of any spilt diesel would evaporate within hours, and in particular, the primary toxic components of diesel (toluene, xylene and benzene) are light and expected to evaporate rapidly.

The likelihood of pollution or contamination of marine waters or sediment due to the transport and loading of iron ore in areas beyond the proposed moderate LEP boundary (**Figure 10.1**) are considered to be low due to the proposed material handling procedures (refer **Section 2**).

Table 10.7 – Concentrations of Contaminants of Potential Concern in Groundwater Samples Collected from Boreholes at the Boodarie Site

Parameter	Units	PQL*	ANZECC/ ARMCANZ 99% Species Protection Limit	No. of Samples	Min.	Max.	Median	95^{th} %ile	Dilution of 1:10	Dilution of 1:50
Chromium[a]	µg/L	1.0	7.7	43	2	72	19	62.8	6.28	1.26
Mercury	µg/L	0.1	0.1	33	<0.1	1.4	0.4	1.24	0.12	0.025
Nickel	µg/L	1.0	7.0	36	<1.0	37	13	24.8	2.48	0.50
Selenium[b]	µg/L	2.0	3.0	31	2	26	12	22	2.20	0.44
Vanadium	µg/L	1.0	50	38	4	63	9.5	52	5.20	1.04
Zinc	µg/L	1.0	7.0	47	9	400	43	167	16.7	3.34

** Practical Quantitation Limit*
a Value for chromium III.
b Low reliability trigger value.

Table 10.8 – Physical Parameters Measured in the Groundwater Samples from Boodarie

Parameter	Units	ANZECC/ ARMCANZ 99% Species Protection Limit	Bore 1	Bore 2	Bore 3	Bore 4	Bore 5	Bore 6	Bore 7	Bore 8	Bore 9	Bore 10	Bore 11
Date Sampled			09/02/2011					10/02/2011					11/02/2011
Electrical Conductivity	mS/cm	–	24.0	1.0	23.0	36.0	24.0	76.0	45.0	36.0	31.0	40.0	58.0
pH		8.0 – 8.4	6.4	6.6	6.4	6.4	6.1	7.2	7.3	7.2	6.4	7.4	7.3
Dissolved Oxygen	% sat	90 – no data	82.0	33.0	74.0	34.0	14.0	13.0	6.0	38.0	4.0	7.0	31.0
Temperature	°C	–	31.4	31.7	27.3	30.7	34.9	30.0	30.8	31.2	31.5	31.8	31.2
Turbidity	NTU	20	1.8	14.0	5.4	0.7	1.7	1.5	1.4	2.4	1.0	5.4	16.0

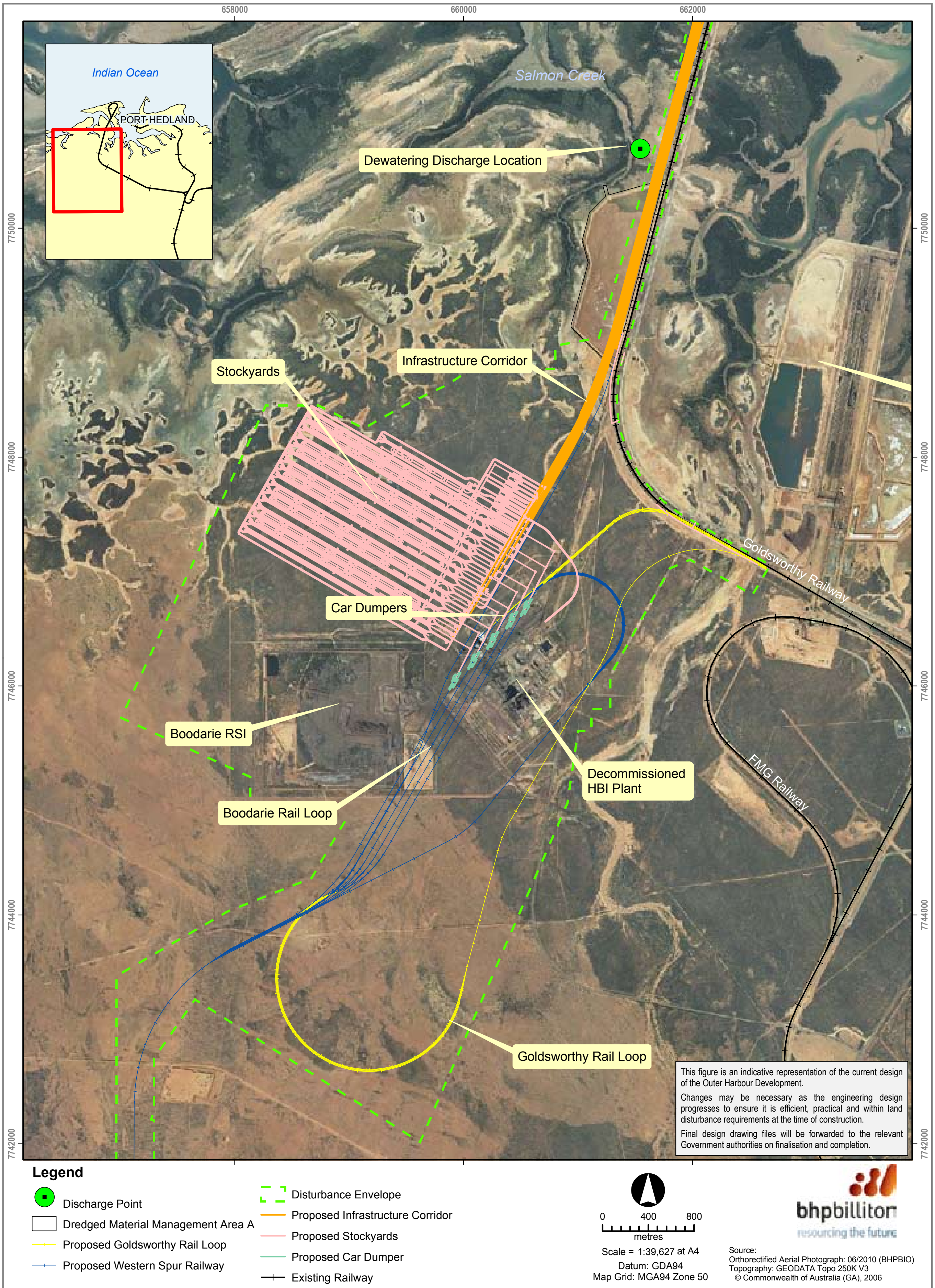

Figure 10.16 Location of Dewatering Discharge Point in Salmon Creek

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Summary of Predicted Impacts

It is possible that leaks and spills of diesel and iron ore to the marine environment may occur, resulting in impacts to marine water and sediment quality. However, if leaks or spills of these substances occur they are likely to be localised and of a short-term nature.

10.2.4.8 Discharge of Stormwater

Stormwater runoff will occur from hard surfaces within on-land infrastructure, in particular the proposed stockyards and transport corridors. Stormwater runoff will be an infrequent discharge associated with significant rainfall events that generate adequate runoff and volume from hard surfaces to create flows.

Stormwater runoff will be diverted from hard surfaces via an integrated stormwater management system that collects stormwater from all hard surface areas and discharges them into permanent water within the tidal creek system of the Inner Harbour. Gross pollutant traps will ensure that litter and other gross pollutants do not enter the tidal creek system.

Contaminants, commonly arising from dust (e.g. iron ore) and road surfaces, may be transported during rain events, particularly during seasonal first flush events. If rainfall events generate sufficient stormwater volumes, then these contaminants may be discharged to the marine environment. These events will be infrequent and the final volume delivered to the receiving environment will be sufficiently minor such that contaminant concentrations will be rapidly diluted within the initial mixing zone. Alternatively, the volumes of stormwater runoff will be such that contaminant concentrations will be lowered within the integrated management system. As a result, the marine environment will receive infrequent, localised contaminant pulses of short duration.

10.2.4.9 Liquid and Solid Waste Disposal during Construction and Operation

No controlled waste (as defined by the *Environmental Protection [Controlled Waste] Regulations 2004*) will be discharged to the marine environment. Controlled wastes and all other non-biodegradable solid wastes will be sent for onshore treatment and disposal or recycling and reuse as appropriate.

10.2.5 Management Measures

Marine water quality will be impacted during the proposed Outer Harbour Development by construction dredging activities and intermittently, during maintenance dredging activities. Impacts to marine water quality will include increased TSS concentrations and sedimentation rates whilst dredging activities are underway. In addition, localised alteration of marine water and sediment quality will result from unconfined ocean disposal of dredged materials. These potential impacts will be managed via proposed avoidance, mitigation, monitoring and contingency measures. The management measures applicable to impacts to marine water and sediment quality arising from construction and operational activities are summarised in **Table 10.9**.

Impacts to marine water and sediment quality arising from dredging and disposal activities will be managed primarily through measures and controls as detailed in the Dredge Spoil Disposal Management and Monitoring Plan (DSDMMP) (**Appendix A3**).

Key management measures proposed within this plan include:

- during transport of dredged material by the TSHD and barges, the level of the overflow pipe will be raised to its highest point to reduce the potential for spillage;
- hopper doors on the TSHD will be well maintained to reduce the potential for sediment loss during transport; and
- TSHDs will be fitted with a turbidity reducing valve within the overflow pipe.

To further inform the implementation of this management plan, a water quality survey will be undertaken to determine seasonal and spatial variability in water quality in State waters of the marine study area over a 12 month period at a fortnightly frequency prior to the commencement of dredging activities. An important output of the survey will be baseline water quality data used for the derivation of water quality trigger values for responsive management. The DSDMMP will be updated based on the results of the surveys prior to commencement of the marine dredging activities.

Impacts to marine water and sediment quality arising from the construction of marine facilities will be managed primarily through measures and controls as detailed in the Marine Facilities Construction Environmental Management Plan (MFCEMP) (to be prepared). A number of management measures applicable to the operation of the marine facilities will be implemented including:

- ballast water will be exchanged in offshore waters prior to berthing at harbour facilities after which ballast water will be discharged into nearshore waters during ore loading activities to maintain vessel stability in line with Australian and international (MARPOL) regulations;
- bilge water from dedicated service vessels will be handled by third party service providers for treatment and disposal; and
- compliance with the International Convention on the Control of Harmful Anti-Fouling Systems on Ships (2001) for any ships utilising the marine facilities.

10.2.6 Significance of Residual Impact

Marine water and sediment quality will be impacted during construction dredging activities for the proposed Outer Harbour Development. The impacts to marine water and sediment quality however will be confined to the proposed dredging periods and the management and monitoring measures proposed will lead to a reduction in the extent and severity of impacts.

Dredged material to be disposed of at spoil grounds is considered acceptable for unconfined ocean disposal. Material disposed of at the spoil grounds will be monitored during post-completion surveys to ensure spoil has been disposed of as approved.

Following the completion of construction activities, the return of ambient marine water and sediment quality conditions within the project area is expected. During operation of the marine facilities, compliance with the moderate LEP (90% ecological protection) boundary, as proposed for areas around existing wharves, jetties and ship turning basins (**Figure 10.1**) will be achieved. The boundary includes an area extending out radially 250 m from the proposed infrastructure that lies within State managed marine waters.

10.2.7 Predicted Environmental Outcomes

The predicted environmental outcomes for marine water and sediment quality of the proposed Outer Harbour Development are:

State

- Although marine water and sediment quality will be impacted during construction activities of the proposed Outer Harbour Development, return of ambient marine environmental conditions is expected upon completion of construction.
- The EPA's objectives for maintenance of fresh and marine water quality in the Pilbara region of Western Australia will be achieved via implementation of the proposed moderate LEP boundary to marine infrastructure.

Commonwealth

- Although impacts to marine water and sediment quality will occur at spoil ground disposal locations, disturbances will be temporary and localised.
- Thorough environmental assessment of material to be dredged demonstrates that it is suitable for unconfined ocean disposal.

10.3 Key Factor – Marine Habitat

The following sub-sections present the assessment of impacts on marine habitat associated with the construction and operation of the Outer Harbour Development, incorporating design modifications, mitigation and management measures applied to manage predicted impacts.

10.3.1 Management Objectives

The management objectives that will be applied to the project for the environmental factor of marine habitats are:

- 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; and
- to maintain the integrity, ecological function, and environmental values of the seabed and coast.

10.3.2 Description of Factor

Benthic primary producers (BPPs) and benthic primary producer habitat (BPPH) is defined as follows:

- BPPs are those organisms which photosynthesise (e.g. macroalgae and seagrasses) and those that contain photosynthesising symbionts (e.g. corals), and
- BPPH is the subset of benthic substrates that does or can support BPPs.

The baseline characteristics of marine habitats within the project area were determined through the studies described in **Chapter 6, Existing Marine Environment**. In particular, the following studies were integral:

- intertidal BPPH survey (SKM 2009l, **Appendix B22**); and
- marine benthic habitat survey (SKM 2009k, **Appendix B21**).

Table 10.9 – Summary of Potential Impacts and Management Actions associated with Marine Water and Sediment Quality

Environmental Aspect	Source	Impacts	Management
Seabed disturbance	Construction Dredging	Reduction in water and sediment quality	*Avoidance/Mitigation/Management Measures:* ▸ A green valve will be used within the hopper overflow pipe of each TSHD. The green valve works by reducing the entrainment of air within the overflow water, and minimises the turbulence (air) in the water column after the overflow water is released back into the marine environment. As a result, the spatial and temporal extent of the dredging plume is reduced. ▸ During sediment transport by the TSHD, the level of the overflow pipe will be raised to its highest point to ensure minimum spillage. ▸ Hopper door seals will be maintained in good condition to ensure minimum loss of material during transport. ▸ Within operational constraints, sailing routes to the disposal grounds will be planned to minimise propeller wash (e.g. utilisation of the channel where possible). ▸ Hopper dewatering will be confined to areas away from sensitive receptors and where practical will only occur within the dredging and spoil disposal areas ▸ Well maintained dredging vessels and properly calibrated equipment will be used. ▸ Dredging vessels will include features such as on-line visualisation of bathymetric charts, loading diagrams, production statistics and vessel movement. *Monitoring:* ▸ Compliance monitoring and associated management responses (benthic community and water quality) will be implemented to effectively manage impacts within the limit of allowable loss during the dredging period in the project area (detail provided in the DSDMMP (**Appendix A3**)). ▸ A tiered trigger level approach will be applied to the areas of potential low impact and potential influence, whereby the exceedance of each subsequent level would result in a greater degree of monitoring and/or management (detail provided in the DSDMP (**Appendix A3**)).
	Maintenance Dredging	Reduction in water and sediment quality	*Avoidance/Mitigation/Management Measures:* On each occasion that maintenance dredging is required for the marine facilities; an impact assessment for the marine environment will be prepared under the requirements of the government assessment guidance documents. This will ensure that environmental risks of maintenance dredging activities have been appropriately assessed on each occasion and that best management practices are applied at the time.
	Ocean Disposal of Dredge Spoil	Reduction in water and sediment quality	Compliance with the Sea Dumping Permit will be met throughout proposed construction dredging and disposal activities.
Liquid and solid waste disposal	Construction and operation of marine facilities	Reduction in water and sediment quality	All waste materials from the dredging vessels including solid waste, hazardous waste and sewage / grey water will be managed as per the requirements of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78) and PHPA requirements. **Solid waste** ▸ Solid waste will be placed in suitable containers (e.g. skip bins) and recycled or disposed of via a licensed contractor. ▸ Clear signage and coverage of wastes will be provided. ▸ Records of waste disposal will be kept.

Table 10.9 – Summary of Potential Impacts and Management Actions associated with Marine Water and Sediment Quality (continued)

Environmental Aspect	Source	Impacts	Management
			Hazardous waste ► Hazardous waste will be stored and labelled in an appropriate manner prior to disposal. ► Empty oil and chemical containers will be returned to the supplier for recycling where appropriate. ► Hazardous waste will be disposed of via a licensed contractor to a licensed hazardous waste facility. ► Records of disposal of hazardous wastes will be kept. **Sewage and grey water** ► An International Maritime Organisation (IMO) certified sewage treatment system will be used on all major vessels. ► All discharge of sewage and grey water will be in accordance with the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Commonwealth)/ MARPOL 73/78 requirements. ► No untreated sewage will be discharged within 12 nm of the nearest land. ► No controlled waste (as defined by the Environmental Protection [Controlled Waste] Regulations 2004) will be discharged to the marine environment. Controlled wastes and all other non-biodegradable solid wastes will be sent for onshore treatment and disposal or recycling and reuse as appropriate
Leaks and spills	Construction and operation of marine facilities	Reduction in water and sediment quality	Hydrocarbon and chemical spills will be managed as per BHP Billiton Iron Ore's Spill Response Procedure outlined in the BHP Billiton Iron Ore ADP EMP (PP-13-100), the dredge contractor's EMP and PHPA requirements. *Preventative management* **Bunkering** Detailed refuelling procedures will be developed by the dredging contractor prior to commencement of work on site and shall include the following requirements: ► Fuel transfer will occur in accordance with port authority and pollution regulations. ► Specific safety boundaries will be used when refuelling. ► Refuelling will only be undertaken in fair weather conditions to reduce risk of spills. ► Open communication channels will be maintained during refuelling. ► Instructions for visual monitoring will be provided. ► Emergency response procedures will be prepared. ► A work instruction will be prepared to provide guidance to crew and staff with regards to minimising the risk of spills during bunkering. ► A pre-task Job Hazard Analysis (JHA) will be undertaken prior to refuelling activities. ► Bunkering will be undertaken using suitable equipment and experienced personnel who will continuously monitor the bunkering equipment and tanks. ► Bunkering will not take place during adverse sea state/weather conditions. ► The rise of the level of fuel in the fuel tank will be constantly monitored during refuelling. ► Fuel hoses will be inspected for signs of wear. ► Spill avoidance devices such as 'dry couplings' and spill trays will be employed. ► Personnel involved with refuelling or fuel transfer will be trained in their roles, functions and responsibility, including emergency response prior to engaging in refuelling or fuel transfer. **Hydraulic Oil Spills** ► The hydraulic oil system will be of a high quality, well-maintained and regularly inspected. ► The main hydraulic system of each dredging vessel will be equipped with standard low pressure/level alarms and shut down systems to minimise hydrocarbon loss in the event of a burst hydraulic hose.

Table 10.9 – Summary of Potential Impacts and Management Actions associated with Marine Water and Sediment Quality (continued)

Environmental Aspect	Source	Impacts	Management
			Storage and Handling ► Hazardous material storage areas will be designed to handle the volumes and operating conditions specifically required for each substance, including product identification, transportation, storage, control and loss prevention (e.g. bunding and drainage). ► Hazardous materials (including hazardous waste) will be stored in appropriately labelled drums or tanks. Complete up to date list of Material Safety Data Sheets (MSDS) will be available and stored with relevant products. ► A MSDS for each chemical will be kept on all vessels. ► Personnel handling hazardous materials will be provided with information and training concerning those materials, as detailed in the MSDS. ► All chemicals and detergents will be stored below deck in appropriate holds. ► Oil and grease drums will be stored below deck in appropriate holds where practicable and space permitting. ► Hydrocarbons stored above deck will be stored within bunded areas to contain any leaks or spills. **Bilge Waters** ► All vessels greater than 400 gross tonnage will have bilge oil/water separators that comply with the requirements of Annex I of MARPOL 73/78 and Part II of the *Protection of the Sea (Prevention of Pollution from Ships) Act 1993* (Cth) to ensure that oil concentrations in discharges are less than 15 ppm. ► No bilge waters with an oil content of more than 15 ppm will be discharged. ► Any discharge of bilge waters will be done whilst en route with oil discharge monitoring, filtering and control systems operating. **Contaminated Deck Wash** ► Drainage from decks and work areas with potential for oil, grease or hydrocarbon contamination will be collected and processed through an oil/water separator and managed according to International Oil Pollution Prevention (IOPP) procedures prior to discharge or stored for onshore disposal. ► Onboard spills will be contained and cleaned up immediately and shall not be washed overboard. Product MSDSs shall be adhered to during clean-up. *Responsive management* Sufficient and appropriate equipment, materials and resources will be available to: ► prevent spills to marine environment from working machinery (e.g. spill trays, one-way valves or other spill prevention features); ► respond to spills to the marine environment; and ► respond to spills to ground (on board vessels). The dredge contractor will comply with and align spill response preparedness with the existing Port Hedland Oil Spill Contingency Plan (OSCP). All vessels shall have a current International Oil Pollution Prevention Certificate (IOPP) issued by the State in which the vessel is registered and an approved Shipboard Oil Pollution Emergency Plan (SOPEP). If vessel does not have an existing approved SOPEP the vessel will prepare a vessel specific Spill Contingency Plan (SCP) that bridges to the Port Hedland OSCP to ensure an effective, integrated response to any spill. Spill response will be undertaken in accordance with onboard oil spill procedures and emergency drills will be conducted as required by vessel management system. Suitable and sufficient oil spill response equipment (spill response kits), including oil absorbent booms and pads, will be available and easily accessible in case of a hydrocarbon spill. Only Australian Maritime Safety Authority (AMSA) approved dispersants will be used at any time.

Table 10.9 – Summary of Potential Impacts and Management Actions associated with Marine Water and Sediment Quality (continued)

Environmental Aspect	Source	Impacts	Management
Stormwater discharge	Construction and operation of facilities	Reduction in water quality	Stormwater drains across the project will collect stormwater from site drains located on roads and culverts. Triple Interceptors will be installed (with a pit for capturing solids and floating hydrocarbons) where stormwater may potentially come from workshops or maintenance areas. The Triple interceptors will have a high level bypass direct to the harbour for large storm events (e.g. cyclone related) where the design limit is exceeded and the priority is to prevent flooding. ► The Triple interceptors will be inspected weekly to observe for hydrocarbons. ► Discharge monitoring will be undertaken and if results indicate high concentrations this will trigger internal investigations. ► Hydrocarbon spill kits will be available across site and managed by the workshops and plant areas. Training will be provided in the use of these products, and the Warehouse will manage inventory levels of replacement products and the kits will be inspected weekly and replenishes stocks. ► Oily Waste and Waste Oil will be controlled by separate waste systems in each of the workshops ensuring separation of the waste from general run-off. ► Specific management: • stormwater egress will not drain into hydrocarbon storage areas. • all clean water will run off into the environment via sumps and infiltration basins. To prevent surface water contamination, storm water will be diverted around the boundary of the stockyards with the use of cut-off drains to collect and divert surface flows. Where possible drainage networks within the Project will be connected to Controlled Discharge Basins for storage and release reuse. • normal clean runoff will be redirect as much as possible to the water recycling facilities, to be treated and reused. • hydrocarbon waste will be segregated from stormwater and other water via closed systems. • all hydrocarbons will be stored in lube facilities etc, and these areas are subject to regulations about bunding and water separators etc. ► All discharge from site must contain less than 5mg/L hydrocarbons.
Physical presence	Construction and operation vessels	Reduction in water and sediment quality	All vessels under control of the Proponent will comply with the International Convention on the Control of Harmful Anti-fouling on Ships as monitored by AQIS.

Marine habitats extend from above the high water mark on land through to the subtidal environment. Specifically, the following categories of habitat types and their occurrence within the proposed Outer Harbour Development area have been applied in the impact assessment:

- **onshore intertidal habitats**: marine habitats occurring above the highest astronomical tidal boundary and including the habitat types of mangroves, cyanobacterial mats and salt marsh (or samphires);
- **coastal intertidal habitats**: marine habitats occurring between the highest and lowest astronomical tidal boundaries and including the habitat types of platform reef and tidal flat;
- **State subtidal habitats**: marine habitats occurring offshore of the lowest astronomical tidal boundary within State waters and including the habitat types of hard and soft substrate; and
- **Commonwealth subtidal habitats**: marine habitats occurring offshore of the lowest astronomical tidal boundary, offshore of the State jurisdiction boundary, and including the habitat types of hard and soft substrate.

To summarise, **Figure 10.17** shows where these marine habitat categories occur within the proposed Outer Harbour Development area.

Baseline surveys of onshore intertidal marine habitats in the project area were undertaken at 16 sites in December 2007 (SKM 2009l). Relevant key findings include:

- the intertidal areas are typical of arid zone coastlines of north-western Australia, characterised by dense stands of mangroves along seaward margins of tidal channels and creeks;
- of the seven species of mangrove recorded:
  - two of the species are locally rare and sparsely distributed in the harbour;
  - all species are widespread throughout northern Australia; and
  - none are listed as threatened under the EPBC Act or the WC Act.
- the upper intertidal areas are a mosaic of samphires (*Tecticornia halocnemoides*) and other salt marsh plants, cyanobacterial mats and large areas of bare substrate.

A desktop assessment of coastal intertidal marine habitats, those areas encompassed by the coastline and lowest astronomical tide boundaries, was undertaken to evaluate the habitat categories present and the extent of those categories. Relevant key findings in defining marine habitats in the coastal intertidal included:

- the full extent of the costal intertidal comprised 21,691 ha;
- two habitat categories were defined: sediments and hard substrates supporting mixed assemblages comprising 20,397 ha and 1,294 ha of the total habitat extent, respectively; and
- field surveys of the intertidal platform at Finucane Island found hard substrates supporting a mixed assemblage community including mainly macroalgae and motile and non-motile invertebrates (sponges, echinoderms and molluscs), present in the zonations of lower, central and upper intertidal. Hard corals were also observed however these were confined to the lower intertidal zone.

Baseline surveys of subtidal habitats were undertaken between December 2007 and May 2008 (SKM 2000j). Relevant key findings to both State and Commonwealth marine areas include:

- the majority of the total marine study area (over 80%) is bare and sandy;
- hard substrate mainly associated with areas on limestone ridges, shoals and rocky pavement near islands comprised 7% of the total area;
- benthic communities inhabiting hard substrate areas were a mosaic of organisms including BPPs (e.g. hard corals and macroalgae) as well as non BPPs (e.g. soft corals, sponges and other sessile invertebrates); and
- non-BPP sponges and soft corals extended onto the plains between ridges, at decreasing densities with distance from the ridges.

The most distinctive characteristics of State subtidal habitats were:

- the greatest diversity and abundance of macroalgae was observed at Little Turtle Island; and
- the most extensive seagrass observed throughout the total marine study area was approximately 86 ha of *Halophila ovalis* found inshore of Weerdee Island.

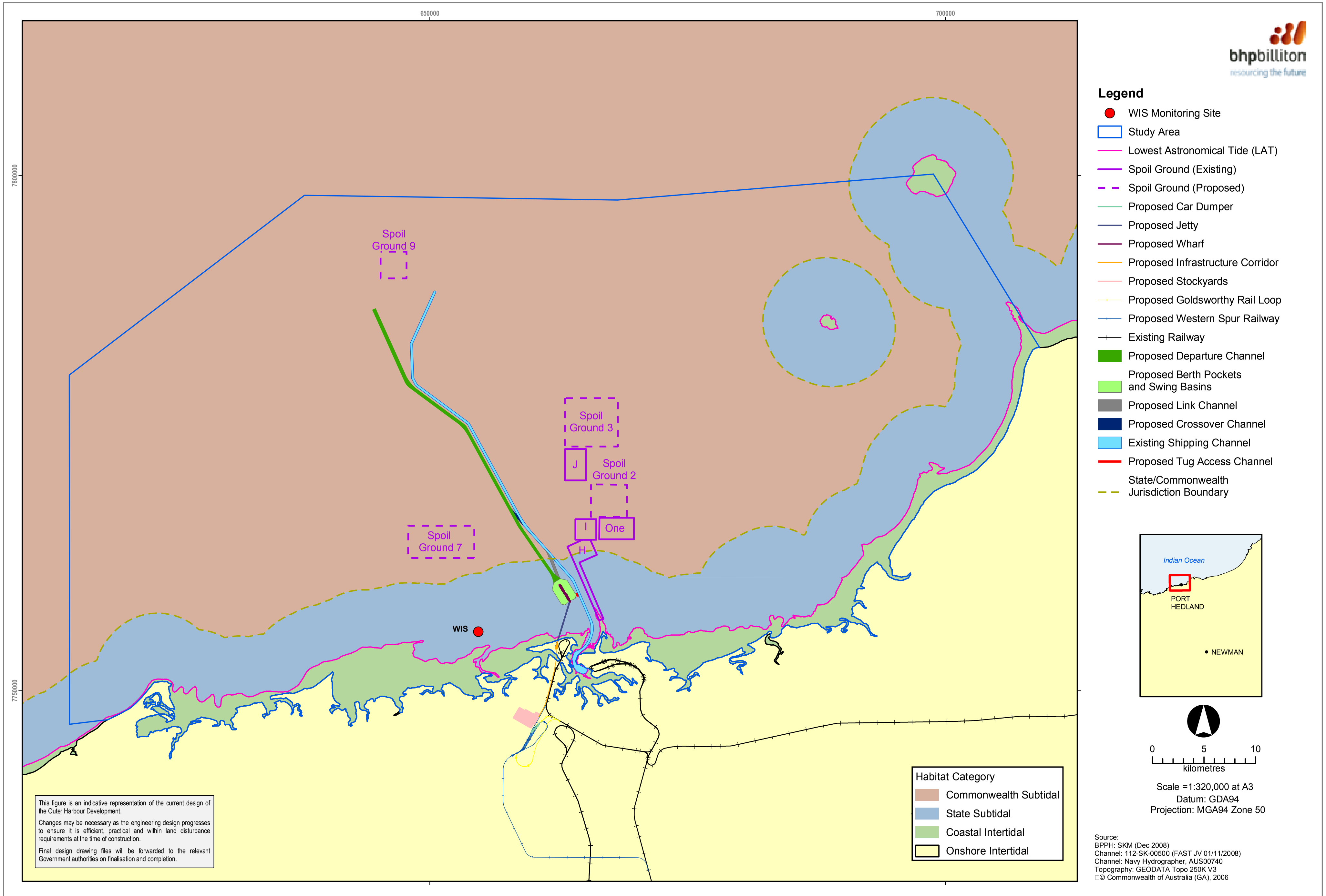

Figure 10.17 Location of Marine Habitat Categories within the Proposed Outer Harbour Development Area

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The most distinctive characteristics of Commonwealth habitats were:

- the greatest diversity of hard coral taxa, and cover, within the project area was recorded at monitoring locations in Commonwealth waters; and
- the most dominant genera within Commonwealth waters were *Turbinaria* and *Acropora*.

A summary of the marine habitats within the marine development footprint is provided in **Table 10.10**.

10.3.3 Assessment Guidance

Guidance on the assessment of impacts to BPPH and BPPs exists at a State level. In addition, impacts to benthic habitats of interest to Matters of National Environmental Significance have been considered at a Commonwealth level. A summary of the assessment guidance documents relating to the management of marine habitat considered in this impact assessment is provided in **Table 10.11**.

Table 10.10 – Summary of Marine Habitats within the Proposed Outer Harbour Development Area

Habitat Type	Total Area (ha)	State (ha)		Commonwealth (ha)
		Inside PHI LAU*	Outside PHI LAU*	
Onshore Intertidal				
Mangroves	2,640	2,640	–	–
Samphire	Under study	Under study	–	–
Cyanobacterial mats	Under study	Under study	–	–
Coastal Intertidal				
Sediment	20,820	3,782	17,038	–
Mixed assemblage	1,364	498	866	–
Mangroves	116	–	116	–
Subtidal				
Hard substrate	365,453	898	7,230	35,531
Sediment			79,591	242,203
Hard coral	18,085.1	0.48	4,937	13,148
Macroalgae	16,025.9	162.1	3,083	12,781
Seagrass	86.0	–	86	–
Soft coral	3,400	0.33	733	2,667
Sponges	8,000	11.1	1,521	6,469
Sessile invertebrates	20,275	–	2,823	17,452

** LAU is a Local Assessment Unit. A full description of the LAUs used for the impact assessments of each of the marine BPPH categories is provided in* Section 10.3.4.

Table 10.11 – Legislation and Guidance Documents Specific to Marine Habitat

Document	Description
Guidance Statement No. 1 – Guidance Statement for the Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (EPA 2001).	Addresses the protection of tropical arid zone mangroves, habitats and dependent habitats along the Pilbara coastline from Cape Keraudren at the southern end of the Eighty Mile Beach to Exmouth Gulf. Requires an estimate of historical and cumulative losses of mangroves.
Environmental Assessment Guideline No. 3 – Environmental Assessment Guidelines for Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment (EPA 2009).	Provides an assessment framework for impacts to BPPH and requires an estimate of historical and cumulative losses of BPPs and their habitats.
Environmental Assessment Guidelines No. 7 – Marine Dredging Proposals (EPA, 2010)	Provides a spatially-based framework for the presentation and assessment of impacts on benthic communities and habitats that are predicted to arise from marine dredging.

Guidance Statement No. 1

These guidelines deal specifically with the EPA's position on development proposals which have the potential to impact directly or indirectly on mangroves, and/or other BPPs in intertidal habitats, and result in irreversible loss, or serious damage to these habitats.

Guidance Statement No. 1 (EPA 2001) recognises mangroves as being an integral part of the coastal ecosystem which are likely to come under pressure from development and therefore management of impacts would be required. The Guidance Statement provides information that the EPA will consider when assessing proposals where tropical arid zone mangroves, habitats and dependent habitats along the Pilbara coastline are relevant environmental factor(s) in an assessment.

In relation to the mangroves of Port Hedland Harbour, the Statement makes the following important determinations:

- the relevant local assessment unit for assessment of mangroves in the Port Hedland region is the Port Hedland Industrial Area Local Assessment Unit (LAU) as defined in the Guidance Statement;
- the mangroves inside the LAU are placed in the category of F[7]; and
- covers all other mangrove areas that occur inside areas that have been designated as industrial areas, associated ports or other development and are not covered by Guideline 3 (EPA 2001).

Environmental Assessment Guideline No. 3

EAG No. 3 (EPA 2009) requires an estimate of historical and cumulative loss of BPPs and their habitats to be developed for each BPPH type in each local assessment unit (LAU). Within the guideline, the following definition of the LAU is provided:

'*The LAU is generally geomorphologically determined, …and defined considering local biophysical and geomorphic features, …taking into account key physical and biological ecosystem attributes such as bathymetry, water circulation patterns, habitat and substrate types etc.*'

Environmental Assessment Guideline No. 7

The stated aim of Draft EAG No. 7 (EPA 2010b) is to provide a spatially-based assessment framework to guide proponents in the clear and consistent representation of predicted impacts associated with marine dredging proposals – both direct and indirect impacts of dredging on benthic communities and habitats are considered.

A summary of the definitions used in EAG No. 7 to describe impacts to benthic communities and habitats is provided in **Table 10.12**.

Table 10.12 – List of Terms Used to Define Impacts to Benthic Communities and Benthic Habitats (EPA 2010b)

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.

10.3.4 Potential Impacts

Potential impacts on the marine habitat resulting from aspects associated with the proposed Outer Harbour Development are discussed below and summarised in **Table 10.28**. The key aspects that directly impact marine habitat are:

- seabed disturbance during dredging, spoil disposal and construction;
- the physical presence of permanent infrastructure; and
- the alteration of marine water quality as a result of dredging and spoil disposal activities.

In particular, dredging and construction activities are proposed in both State and Commonwealth marine areas, while dredge spoil disposal is proposed only for locations in Commonwealth marine areas. Water quality impacts arising from dredging and disposal activities are predicted in both State and Commonwealth marine areas.

The requirements of the environmental assessment guidelines summarised above are particular for BPPH in State waters only. As such, these requirements have been applied to impact assessments of BPPH in State waters only. Impacts to habitats have also been assessed for Commonwealth waters, however these are considered in the context of, *how significant are impacts to habitats supporting Matters of National Environmental Significance?*

7 Guidance Statement No. 1 covers mangroves that are inside ports or other developed areas, but are not considered regionally significant.

In light of the varying spatial assessment requirements and project aspects, the structure of this section is as follows:

- **Onshore Intertidal Habitats**: impacts to mangroves are assessed in accordance with requirements of Guidance Statement No. 1 and EAG No. 3;
- **Coastal Intertidal Habitats**: impacts to BPPH are assessed in accordance with requirements of EAG No. 3;
- **State Subtidal Habitats**: impacts to BPPH within State waters are assessed in accordance with requirements of EAG Nos. 3 and 7; and
- **Commonwealth Habitat Considerations**: impacts to benthic habitats in spoil disposal areas, and habitats potentially supporting conservation significant species, are assessed.

10.3.4.1 Onshore Intertidal Habitats

The following sections summarise the assessment of impacts to intertidal habitats, including mangroves, due to the proposed Outer Harbour Development. A detailed impact assessment is included in **Appendix B30**.

Mangroves

In determining the total cumulative losses for onshore intertidal (mangrove) BPPH, the following components have been derived:

- present distribution;
- direct loss; and
- historical and cumulative losses.

Present Distribution

The total area of mangroves estimated to be present in 1963 is 2,699 ha. Revision of mangrove extent based on imagery from 2008 has resulted in a revision to 2,640 ha (**Table 10.13**). The revised estimates of loss based upon the current status of mangroves present in 2008 (SKM 2009b) show that losses of mangroves to date have been offset by gains in mangrove areas during the last 45 years. It is possible that some of the apparent gains in mangrove vegetation are due to errors in the estimates between 1963 and 2008 and there is no doubt that for the vegetation association *Avicennia marina* (scattered) the delineation of landward boundaries of open canopy forest is problematic. However, a comparison of the areas of the closed canopy forest vegetation associations, which are much more clearly delineated, shows that there have been substantial losses of some vegetation associations but also some substantial gains such that the estimated net loss of mangroves between 1963 and 2008 is 2.2%.

Direct Loss

The expected direct loss of mangrove BPPH due to construction of the proposed West Creek crossing and infrastructure corridor has been estimated at 27.0 ha (**Table 10.14** and **Figure 10.18**).

Table 10.13 – Cumulative Changes in Extent of Mangrove Associations in 1963 and 2008

Vegetation Association	1963 total (ha)	2008 total (ha)	% Cumulative losses or gains
Avicennia marina (closed canopy, seaward edge)	223	220	-1.3
Rhizophora stylosa (closed canopy)	570	589	+3.3
Rhizophora stylosa/Avicennia marina (closed canopy)	126	89	-29.6
Avicennia marina (closed canopy, landward edge)	891	1,027	+15.3
Avicennia marina (scattered)	889	715	-19.6
Totals	**2,699**	**2,640**	-2.2

Table 10.14 – Estimated Loss of Mangrove Habitat Associations due to the Proposed Outer Harbour Development

Vegetation Association	Proposed Loss (ha)
Avicennia marina (closed canopy, seaward edge)	1.5
Rhizophora stylosa (closed canopy)	5.5
Avicennia marina/Rhizophora stylosa (closed canopy)	2.0
Avicennia marina (closed canopy, landward edge)	7.0
Avicennia marina (scattered)	11.0
Total	**27.0**

The greatest mangrove association loss is estimated to occur within the *A. marina* (scattered) mangrove vegetation association (11.0 ha), followed by the *A. marina* (closed canopy, landward edge) habitat (7.0 ha). These two vegetation associations occupy the highest intertidal positions of the five mangrove vegetation associations under consideration. It is considered that the contribution to environmental function by association category decreases with increasing shore height, and as such the conservation of low-intertidal mangrove habitat is of high importance. The closed canopy, seaward edge *Avicennia marina* forest in the low intertidal zone would be the least impacted of the mangrove vegetation associations, with estimated loss of 1.5 ha, while the losses of high value stands of *Rhizophora stylosa* would be up to 5.5 ha.

The proposed infrastructure corridor causeway over West Creek will influence the tidal flushing of the creek. The causeway design includes culverts to maintain water flow during tidal exchange and therefore the alteration of the flushing regime (APASA 2009b) will not be sufficient to have a measurable impact on the creek's fauna and flora. Water flow through the culverts may cause temporary ponding of water behind the causeway when the tide is falling and delay inundation when the tide is rising. These effects are likely to be most noticeable during spring tides.

A decrease in the flushing rate may cause sediments to accumulate on the seabed behind the causeway. In addition, slow moving water exiting through the culverts may result in additional sediment being deposited upstream of the culverts. It is unlikely that sediment accumulation will impact the mangroves currently fringing the banks of the creek. It is more likely that enhanced sedimentation upstream of the culverts will increase the area of substrate available for colonisation by new mangroves. A detailed tidal flushing impact assessment in contained within **Appendix B31** (APASA 2009b).

Construction earthworks and vehicle movements could result in dust being deposited on surrounding mangroves. Particulate material can negatively impact plants by blocking small pores in their leaves called stomata. The stomata are critical for plants in performing transpiration[8]. Research undertaken by BHP Billiton Iron Ore and CSIRO demonstrated that particulate material in particular, iron ore dust particles, settling on mangroves did not block mangrove leaf stomata or restrict transpiration, and did not significantly impact the condition of the mangrove vegetation within the Port Hedland region (Paling *et al.* 2001).

Historical and Cumulative Losses

Table 10.15 provides an estimate of the cumulative loss of mangrove habitat within the Port Hedland Industrial LAU, including the approved losses for the recent project proposals for Utah Point (PHPA) and RGP5 (BHP Billiton Iron Ore), and proposed losses for RGP6 (BHP Billiton Iron Ore) and South West Creek (PHPA).

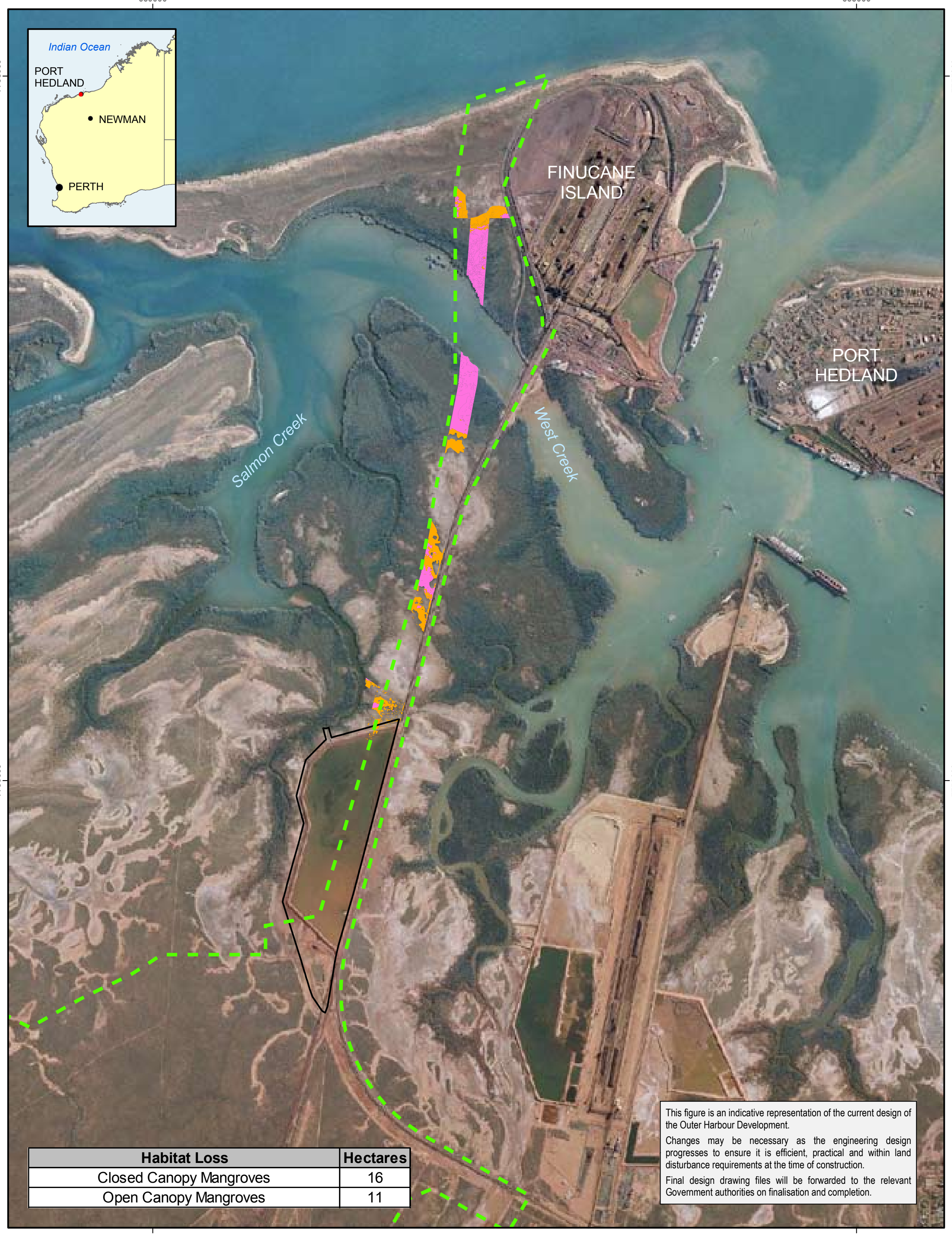
The calculation of actual net loss (2,699 ha – 2,640 ha = 59 ha) between 1963 and 2008 was calculated from an image set captured in 2008 where none of the approved mangrove losses for recent project proposals had yet occurred and therefore the total cumulative loss as at 2008 was 2.2% (59 ha/2,699 ha).

Since then, additional proposed development within the Management Unit such as Utah Point (18.6 ha), RGP5 (6.5 ha) and RGP6 (4.0 ha) have been approved and/or have proceeded. If the projected loss of mangroves for the proposed South West Creek Development (40.0 ha) is also approved, then the approved cumulative loss from existing net losses (59 ha), plus the approved losses since the

8 Transpiration is the process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapour and is released to the atmosphere.

Table 10.15 Historical and Cumulative Loss of Mangrove BPPH in Port Hedland Industrial LAU using Revised Estimates

Management Unit	2008 Extent of Mangroves	Losses since 2008 Mangrove Area Estimate	Cumulative Loss (%)	EPA (2009) Category and Loss Threshold
Port Hedland Industrial Area (154.3 km^2)	2640 ha	► PHPA Utah Point – 18.6 ha ► BHP Billiton Iron Ore RGP5 – 6.5 ha ► BHP Billiton Iron Ore RGP6 – 4.0 ha ► Roy Hill Iron Ore 5.0 ha ► PHPA South West Creek – 40.0 ha **Cumulative loss since 2008 = 74.1 ha**	2.2% from 2008 estimate	E – 10%
Port Hedland Industrial Area (154.3 km^2)	Current extent of mangroves 2565.9 ha	*Worst-case loss scenario:* Port Hedland Outer Harbour project: 27 ha	5.7%	



Habitat Loss	Hectares
Closed Canopy Mangroves	16
Open Canopy Mangroves	11

Legend

Vegetation Association (2008)

- DMMA A Construction Footprint
- Closed Canopy Mangroves
- Open Canopy Mangroves

0 200 400 600 800
metres
Scale = 1:35,000 at A4
Datum: GDA94
Projection: MGA94 Zone 50

Figure 10.18 Estimated Loss of Mangrove Primary Producer Habitat from the Proposed Infrastructure Corridor

bhpbilliton
resourcing the future

Source:
Orthorectified Aerial Photograph: 06/2008 (BHPBIO) Topography: Geoscience Australia, GEODATA Topo 250K V3 (Copyright Commonwealth of Australia, 2006)
Mangrove: Based on 2008 Reclass of PTHE_ORTHOREG_35K_0608.ecw

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2008 image was captured (69.1 ha) means that the cumulative loss is 4.7% (128.1 ha of the 2,699 ha). With the addition of the worst-case scenario for mangrove loss from the proposed Outer Harbour Development (27.0 ha), the cumulative loss of mangroves would rise to 5.7% (155.1 ha of the 2,699 ha). This is still within the cumulative loss guidelines of 10% for developed areas (loss threshold category E – 10%).

In summary, the total area of mangrove loss due to the proposed Outer Harbour Development project is 27.0 ha due to direct removal, primarily within *A. marina* (scattered; 11.0 ha) and *A. marina* (closed canopy, landward edge; 7.0 ha) habitat. When applying the mangrove extent according to 2008 imagery the total cumulative mangrove loss is 155.1 ha (or 5.7%).

Samphire and Cyanobacterial Mats

The vegetation within the area under or near the proposed West Creek causeway that may be impacted, includes scattered samphires. This area is located on Finucane Island, bounded by the access road that leads to the western tip of the island and by the mangroves on the seaward side. In addition, scattered samphires are present on the mainland, on the western side of the old conveyor causeway. The area of samphire habitat that may be impacted by the proposed activities has not been mapped accurately due to uncertainty with respect to discrete boundaries of this habitat area. This in turn makes it difficult to accurately discriminate between bare tidal flat and potential samphire habitat, and between mixed samphire and scattered mangrove. As such, a quantitative loss assessment of samphire habitat has not been undertaken.

Within the footprint of the proposed West Creek causeway, historical observations of cyanobacterial mat distribution show an area of no more than 0.25 ha occupied by mats. The area of potential algal mat habitat may be larger, particularly in years when environmental conditions (e.g. heavy rainfall) are favourable to the presence of this BPP. It is therefore difficult to determine the area or potential area of cyanobacterial mats that may be present due to their seasonal nature. As such, a quantitative loss assessment of cyanobacterial mat habitat has not been undertaken.

Coastal Intertidal Habitats

The following sections summarise the assessment of impacts to coastal intertidal habitats due to the proposed Outer Harbour Development in accordance with the requirements of EAGs No. 3 and No. 7. Greater detail on the impact assessment of coastal intertidal habitats is included in **Appendix B2** and **B3**.

In accordance with EAG No. 3, boundaries for Local Assessment Units (LAUs) have been determined and impacts considered within each LAU where perturbations to water quality or removal/disposal of material is predicted or proposed. The LAUs and their boundaries have incorporated the following considerations:

- LAUs will be approximately 50 km^2 in area; and
- as the LAUs are intended to assess impacts to coastal intertidal BPPH, the coastline to highest astronomical tide form the boundaries of this habitat category.

The proposed LAUs and their boundaries are presented in **Figure 10.19** and the total coastal intertidal areas encompassed by each unit are provided in **Table 10.16**. It should be noted that the Port Hedland Industrial LAU is an existing LAU within the region and as such has been incorporated into this assessment framework.

Table 10.16 – Proposed Local Assessment Units and their Boundaries for the Impact Assessment of Coastal Intertidal BPPH

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

In determining the total cumulative losses for coastal intertidal BPPH, the following loss components have been derived:

- historical losses;
- direct losses due to removal; and
- indirect losses resulting from dredging induced impacts.

With respect to the indirect losses of coastal intertidal BPPH resulting from dredging induced impacts, these are due to increased sedimentation rates associated with dredging activities. In particular, the predicted losses due to sedimentation relate to the zones of impact and tolerance thresholds prepared for the subtidal BPPH impact assessment. These impact assessment tools are described in detail below under **Subtidal BPPH Impact Assessment** and in **Appendix B2**.

Historical Loss

Historical loss of coastal intertidal BPPH has occurred during disposal of dredged material to the 'Spoil Bank'. The exact extent of historical BPPH loss due to this spoil disposal activity is difficult to determine because there is no baseline habitat data or mapping available prior to the first dredging and disposal activities. The detailed habitat mapping carried out for the proposed Outer Harbour Development is the first time the coastal intertidal marine habitat in the Port Hedland region has been quantified and it is this mapping that has been used to make estimates of historical losses provided here.

Table 10.17 provides an estimate of the coastal intertidal habitat lost due to the historical disposal of dredged material to the Spoil Bank area, and is illustrated in **Figure 10.20**. This estimated loss falls within the Port Hedland Industrial LAU.

Direct Loss

Direct loss of coastal intertidal BPPH will occur in the project footprint from construction of the jetty and adjoining abutment of approximately 1.7 ha of beach and the upper intertidal rock platform (**Figure 10.21**). The estimated areas of BPPH directly impacted by these activities are summarised in **Table 10.18** and falls within the Port Hedland Industrial LAU.

Indirect Loss

No indirect losses of coastal intertidal BPPH are predicted for the proposed Outer Harbour Development (**Figure 10.22**).

Cumulative Losses

A summary of the historical loss estimated for the coastal intertidal region (69 ha) and direct loss during construction of the jetty and abutment (1.7 ha) is provided in **Table 10.19**. Based on these losses, the total cumulative loss of coastal intertidal BPPH will be approximately 70.7 ha, with a resultant percentage loss of 14.2% in the Port Hedland Industrial LAU.

Table 10.17 – Historical Losses of Coastal Intertidal BPPH

LAU	Estimated Original Area (ha)	Historical Loss		EPA (2009) Category and Loss Threshold
		(ha)	%	
Port Hedland Industrial LAU	498	Spoil Bank Disposal: 69	13.9	E – 10%

Table 10.18 – Direct Losses of Coastal Intertidal BPPH due to the Proposed 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 LAU	498	Jetty and abutment: 1.7	1.7	0.3	E – 10%

Table 10.19 – Total Cumulative Losses of Coastal Intertidal BPPH due to the Proposed Outer Harbour Development

LAU	Total Area of BPPH (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**	**–**	**–**

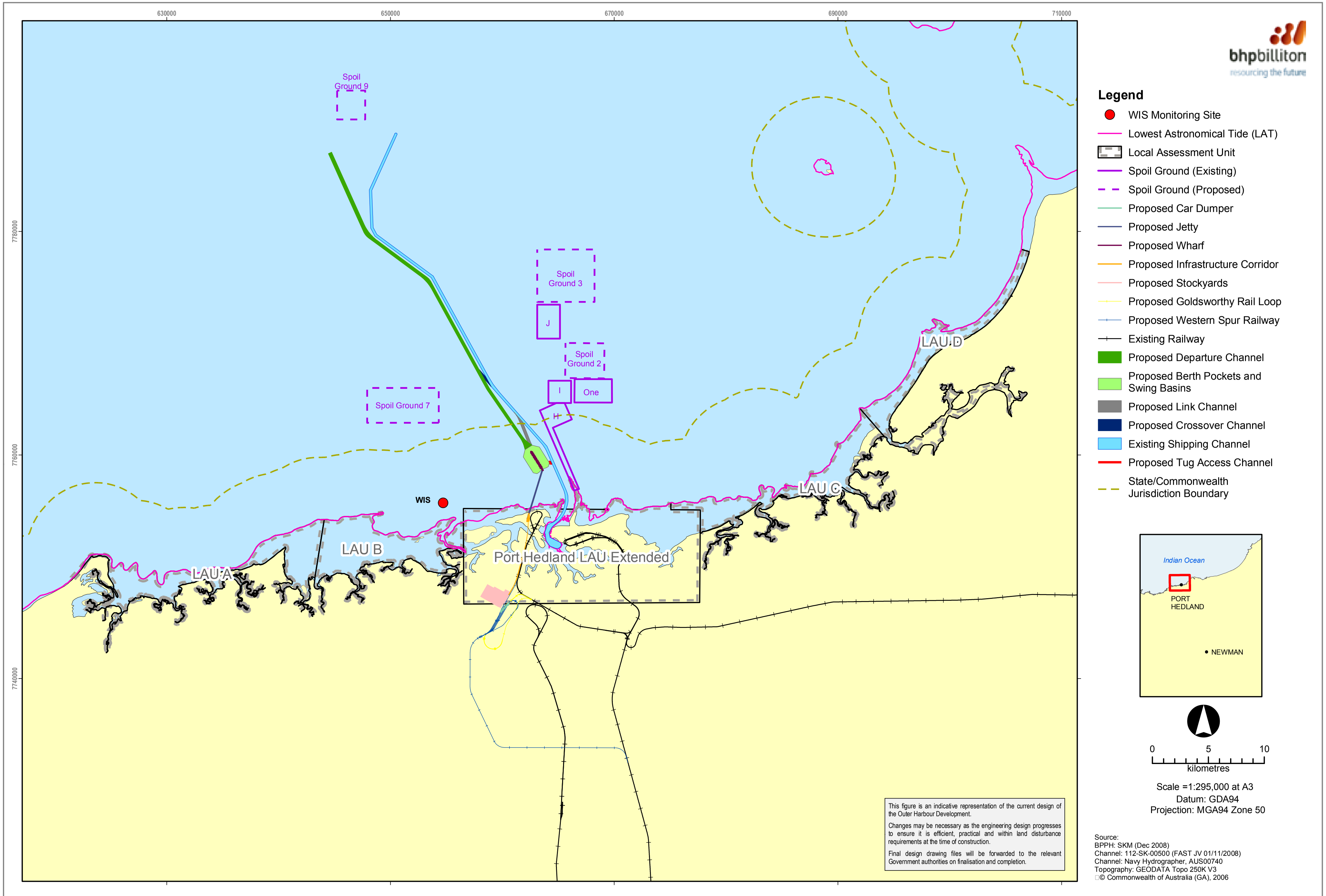

Figure 10.19 Local Assessment Unit Boundaries for Assessment of Impacts to Coastal Intertidal Benthic Habitats for the Proposed Outer Harbour Development

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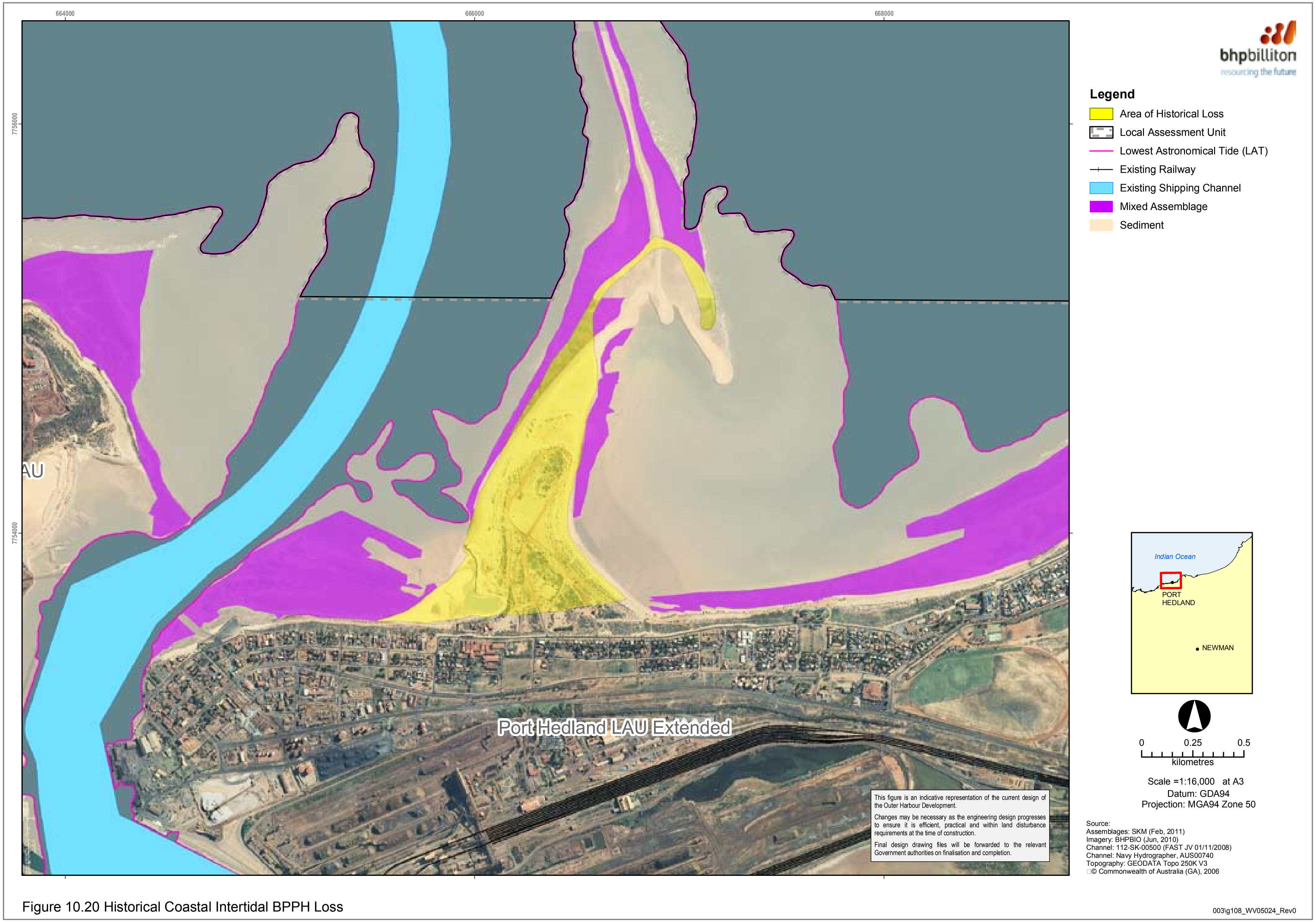

Figure 10.20 Historical Coastal Intertidal BPPH Loss

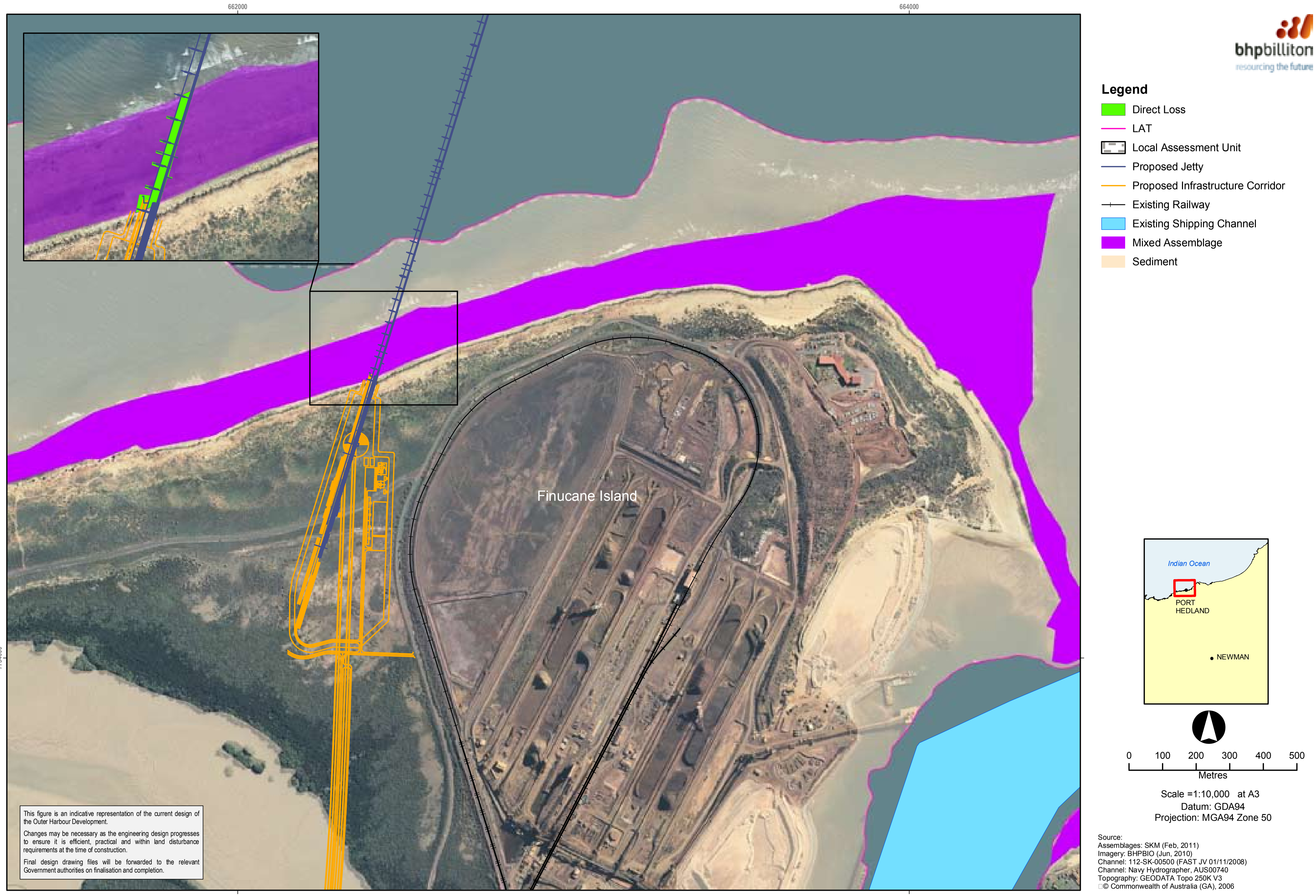

Figure 10.21 Direct Losses of Coastal Intertidal BPPH due to the Proposed Outer Harbour Development

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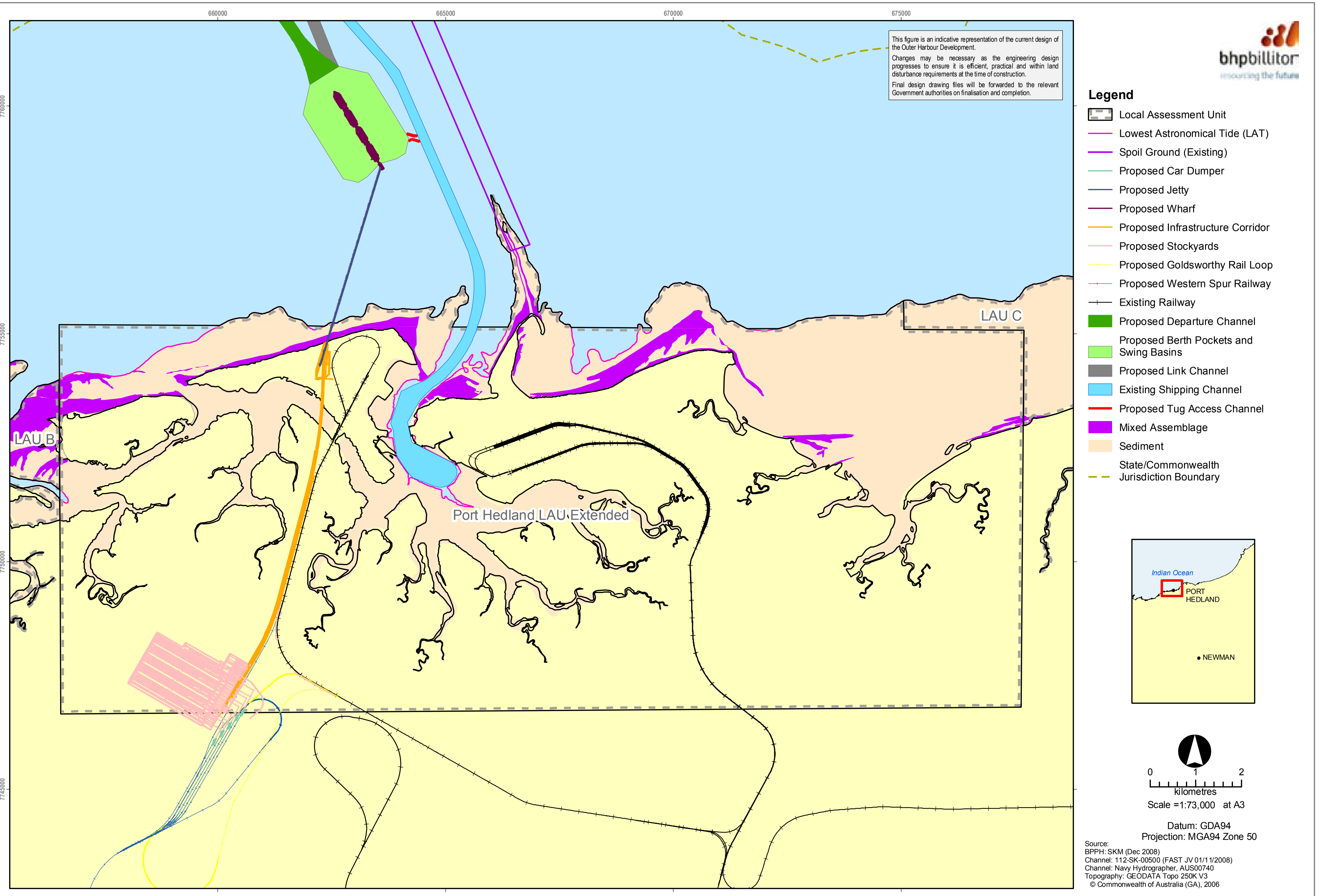

Figure 10.22 Predicted Irreversible Losses of Coastal Intertidal BPPH due to Elevated Sedimentation Rates

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10.3.4.2 State Subtidal Habitats

The following sections summarise the assessment of impacts to subtidal habitats within State waters due to the proposed Outer Harbour Development in accordance with the requirements of EAG Nos. 3 and 7. Greater detail on the impact assessment of subtidal habitats is included in **Appendix B2**, and assessment of impacts to subtidal habitats offshore of the State jurisdiction boundary in Commonwealth waters follows below.

Although the BPPH impact assessment presented in this section is confined to State subtidal habitats, this is with the purpose of responding directly to the State Environmental Assessment Guidelines 3 and 7 (refer **Section 10.3.3**). It should be noted however that the sediment plume modelling undertaken to evaluate impacts to water quality due to dredging has been undertaken beyond the State boundary (**Section 10.2**) and any impacts due to dredging beyond the State boundary that may affect BPPH within State waters has been included in the assessment presented below.

In compliance with EAG No. 3, boundaries for LAUs have been determined and impacts considered within each LAU where changes to water quality or removal/disposal of material is predicted or proposed. 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 subtidal BPPH, the lowest astronomical tide mark forms the shoreward boundary; and
- the State waters boundary forms the seaward boundary of the LAU.

The proposed LAUs and their boundaries are presented in **Figure 10.23** and the total subtidal areas encompassed by each unit are provided in **Table 10.20**. It should be noted that the Port Hedland Industrial LAU[9] is an existing LAU within the region and as such has been incorporated into the assessment framework.

Table 10.20 – Proposed Local Assessment Units and their Boundaries for the Impact Assessment of Subtidal BPPH

LAU	Area	
	ha	km^2
1	4,289	42.89
2	4,941	49.41
3	3,580	35.80
4	3,653	36.53
5	4,411	44.11
6	4,767	47.67
7	4,651	46.51
8	5,680	56.80
Port Hedland Industrial LAU	898	8.98
9	4,642	46.42
10	4,438	44.38
11	4,793	47.93
12	4,821	48.21
13	4,429	44.29
14	4,264	42.64
15	4,149	41.49
16	4,109	41.09
17	2,372	23.72
18	6,800	68.00

In addition to outlining LAU boundaries, the State assessment process requires the definition of impact zones in accordance with requirements of EAG No. 7. The zones required are:

- **Zone of High Impact (ZoHI)**: the area directly impacted (e.g. the channel and spoil disposal sites) and immediately around the proposed dredging and disposal 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 within the ZoHI should be considered in the context of EAG No. 3;

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

- **Zone of Moderate Impact (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 organisms, 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 Zone of Influence**: the point beyond which there should be no dredging (or spoil disposal) related deviations 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.

Threshold values were developed for BPPs for which impacts and ultimately losses are predicted to occur. In particular, threshold values were developed for altered water column conditions as indicated by TSS concentrations and sedimentation rates. Provided here is an overview of the thresholds. For further information on the thresholds refer to **Appendix B10**.

The threshold values set to delineate the **Zone of High Impact** are based on TSS concentrations that occlude all light (“no-light”) from reaching the benthic community for four consecutive fortnights.

The threshold values set to delineate the **Zone of Moderate Impact** are based on TSS concentrations that will occlude 40% of light from reaching the benthic community. When these TSS concentrations occur continuously in a 14-day period then this period is termed a “low-light” fortnight. If the “low-light” fortnights are consecutive then impacts on the hard coral community, as a sentinel to the broader BPP community, are assumed to have occurred.

The relationship between the number of consecutive reduced light fortnights that occur and the assigned loss of hard coral were determined using:

- the literature available on the length of “no-light” and “low-light” periods which correspond to hard coral mortality; and
- the periods of “no light” and “low-light” which the hard coral communities at Port Hedland experience from the baseline light climate data already collected, and the measures of mortality of these communities during and after the periods of “no-light” or “low-light”.

Sedimentation threshold values have been estimated from baseline monitoring data collected 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.

Table 10.21 – Decision Rules Used to Determine the Zones of Impact and their Boundaries

Zone	Description of Decision Rule
Zone of High Impact	Anywhere that direct removal of BPPH is predicted to occur; where the benthic environment is predicted to experience one period of four consecutive “low light” fortnights; and where twice the maximum background mean daily gross sedimentation rates is predicted to occur.
Zone of Moderate Impact	Areas predicted to experience one period of four consecutive “low light” fortnights; and where 1.1 times the maximum baseline mean daily gross sedimentation rates is predicted to occur.
Zone of Influence	Water column TSS concentrations are greater than 5 mg/L above background concentrations.
Outer Boundary of the Zone of Influence	Water column TSS concentrations are 5 mg/L or less above background at any point in time.

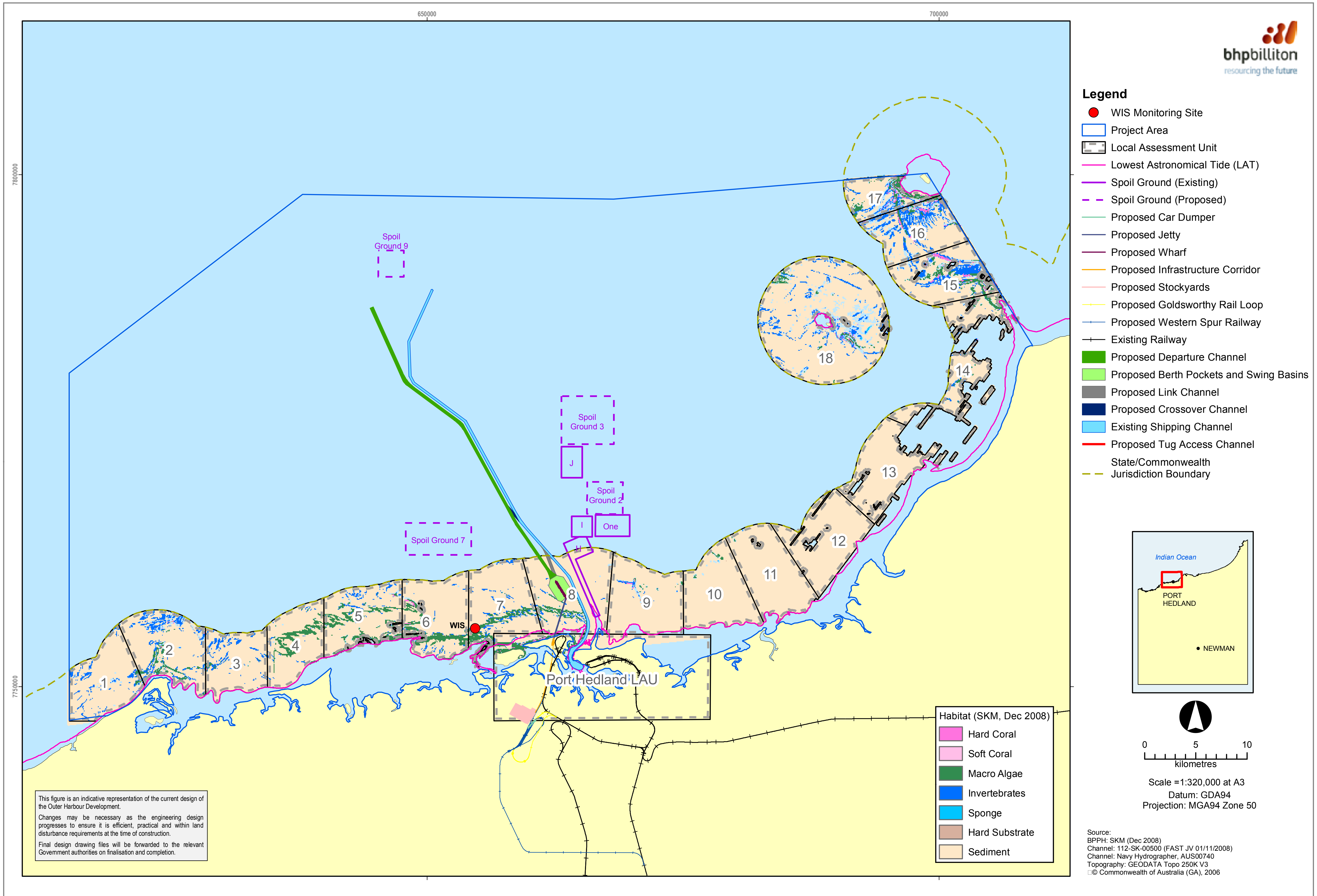

Figure 10.23 Local Assessment Unit Boundaries for Assessment of Impacts to Subtidal Benthic Habitats for the Proposed Outer Harbour Development

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A summary of the decision rules that have been used to determine the impact zones are summarised in **Table 10.21**. **Figure 10.24** illustrates the Zones of Impact within State waters for the proposed Outer Harbour Development.

The sediment plume modelling outputs for TSS concentrations and sedimentation rates were then interrogated using the thresholds described here to predict and plot the boundaries for the zones of impact and influence.

Based on these investigations the following values for hard coral losses due to reduction in the light climate were developed:

- the Zone of High Impact is predicted to experience 100% coral loss if at any stage during the dredging program there is one period of four consecutive "no light" fortnights; and
- the Zone of Moderate Impact is predicted to experience 0% coral loss if at any stage during the dredging program there is one period of four consecutive "low light" fortnights.

Due to a change in the grid pattern used in the sediment plume modelling, there is an anomaly in sediment particle transport where this occurs leading to invalid predictions of high TSS concentrations (for example, near Little Turtle Island as seen in **Figure 10.24**). Compounding this is the increase in cell size in the outer boundaries of the APASA modelling. These factors result in impacts to be over-represented. The over-representations are associated with a data layer used in presenting the modelling outputs. This layer has been removed in **Figure 10.25**, thus removing misrepresentation of predicted impacts. It is this figure and the zones of effect presented therein that have been used in the impacts to benthic communities considered in this assessment.

For further information on the development of threshold values for predicting the zones of impact refer to **Appendix B10**.

In determining the total cumulative losses for subtidal BPPH in State waters due to the project, the following loss components have been derived:

- historical loss;
- direct loss due to removal; and
- indirect loss resulting from dredging induced impacts.

Historical Losses

Historical losses of BPPH within State waters have occurred during the construction and maintenance of the existing channel and turning basins, and through use of spoil grounds and shipping anchorages. 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. The detailed habitat mapping carried out for the proposed Outer Harbour Development is the first time the subtidal marine habitat offshore from Port Hedland has been quantified and it is this map that has been used to make estimates of historical losses provided here.

Within State waters, the historical activities for which loss estimates of BPPH have been made are the access channel and RGP6 (BHP Billiton Iron Ore 2009) (**Figure 10.26**; **Table 10.22**). Although the South West Creek project (EPA 2011) is likely to have impacts on subtidal BPPH in the Inner Harbour, losses were not predicted for that project.

Direct Losses

Direct loss of BPPH will occur in the proposed Outer Harbour Development footprint from construction of the jetty and wharf, from removal of seabed during dredging of the berth area, turning basin and channel (**Figure 10.27**). The estimated areas of BPPH directly impacted by these activities are 7.6 ha (2.5%) and are summarised in **Table 10.23**.

There are no proposed spoil grounds within State waters for the project. BPPH impacts due to spoil disposal are considered below under **Commonwealth Subtidal Habitats**.

Table 10.22 – Historical Losses of Subtidal BPPH within State Waters

LAU	Estimated Original Area (ha)	Historical Loss		EPA Category and Loss Threshold
		(ha)	%	
LAU 8	308	Access Channel: 15	4.9	E – 10%
Port Hedland Industrial LAU	190.07	RGP6: 4.17 South West Creek: 0	2.2 0	E – 10%
Totals	**498.07**	**19.17**	–	–

Table 10.23 – Direct Losses of Subtidal BPPH due to the Proposed 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
LAU 8	308	Departure Channel	0	7.6	2.5	E – 10%
		Link Channel	0			
		Jetty	1.9			
		Berth Pockets and Turning Basin	4.3			
		Tug Channel	1.4			

Indirect Losses

Hard coral assemblages can persist in environments with variable water quality, where light and sedimentation commonly undergo seasonal changes, often as a result of land based sediment inputs and disturbance by cyclones (Edinger *et al.* 2000; Fabricius 2005). Some of the natural perturbations in water quality may stress corals and cause mortality.

Human induced disturbances to water quality may also cause stress and mortality, particularly if the disturbances are more severe and longer lasting than natural perturbations. Human disturbances may create cumulative impacts in conjunction with natural disturbances. High sedimentation rates and light deprivation are both important stressors of hard corals that may ultimately lead to mortality.

High levels of suspended solids caused by dredging and natural events (e.g. cyclones) can cause episodic low light conditions. Reduced light conditions will ultimately impact the photosynthetic capacity of hard corals, limiting their ability to produce energy and affecting their continued viability. It is generally accepted that hermatypic corals will not live in conditions of less than 0.5 to 2% of surface irradiance (for example, Falkowski & Dubinsky 1981; Titlyanov & Latypov 1991). This is because rates of photosynthesis are expected to decrease in low light, unless corals are able to fully acclimatise to the altered light conditions (Falkowski *et al.* 1990). Hence prolonged reductions of light can cause mortality amongst hard coral.

Elevated rates of sedimentation leading to an accumulation of sediment (smothering) are the most likely causes of hard coral mortality from dredging operations. Sedimentation coats hard corals in a layer that they are unable to remove (Nugeus & Roberts 2003). Monitoring programs in nearby locations such as Mermaid Sound (off Dampier and west of the Burrup Peninsula) since the 1980s report that the majority of hard coral mortality can be attributed to localised smothering close to dredging and spoil disposal operations (LDM 1995; LSC 1989; Meagher & Associates 1984, Stoddart *et al.* 2005).

Propeller wash caused by the dredger manoeuvring in shallow areas adjacent to sensitive habitats is of particular focus because it generates large amounts of sediments, which become suspended and subsequently smother benthic biota.

Macroalgae in this region are typically seasonal in both distribution and abundance, and also show inter-annual variation in these key parameters (Huisman & Borowitzka 2004; **Section 6.6.2**). Macroalgae tend to recruit more rapidly into disturbed areas than hard corals and consequently the survival of hard corals is considered a greater management priority than that of macroalgae.

Macroalgae are vulnerable to both sedimentation and low light regimes. Tolerances vary among species (Eriksson & Johansson 2005). Variations in sedimentation and light attenuation have the potential to influence community structure and recruitment success of individual species (Turner 2004). Many macroalgae, even in the same assemblage, have widely different tolerances to sedimentation and turbidity (Fabricius & De'ath 2002; Fabricius *et al.* 2007; Harrington *et al.* 2005; Umar *et al.* 1998). The available information on habitat preferences and seasonal fluctuations in distribution and abundance for some macroalgae suggests it is likely that if there are impacts on macroalgae from sedimentation and turbidity, these will be small scale and the algae are expected to quickly recover from the disturbance (Airoldi 2003).

Water quality conditions in the Zone of High Impact will include very high TSS concentrations (up to 150 mg/L at times in some areas), and extremely elevated sedimentation rates (up to 100 kg/m^2 adjacent to the dredging activities) of very coarse sediment particles. The nature of the predicted water quality perturbations will be such that low and no light conditions will be experienced at the benthos, and because very coarse sediment particles will be falling out of suspension in these areas, it is likely that they will remain where they fall until very strong metocean conditions are experienced (e.g. cyclone).

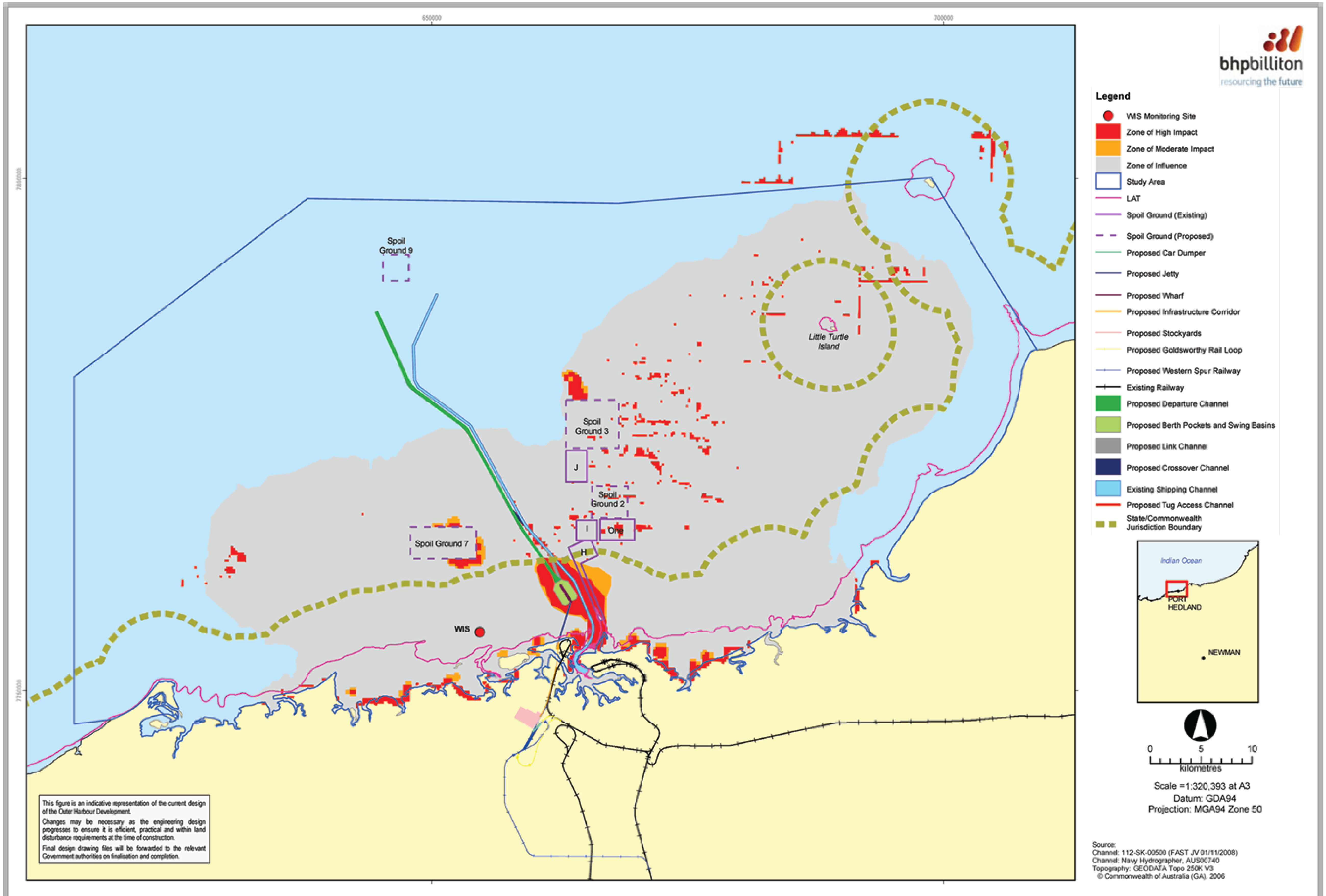

Figure 10.24 Zones of Impact for the Proposed Outer Harbour Development

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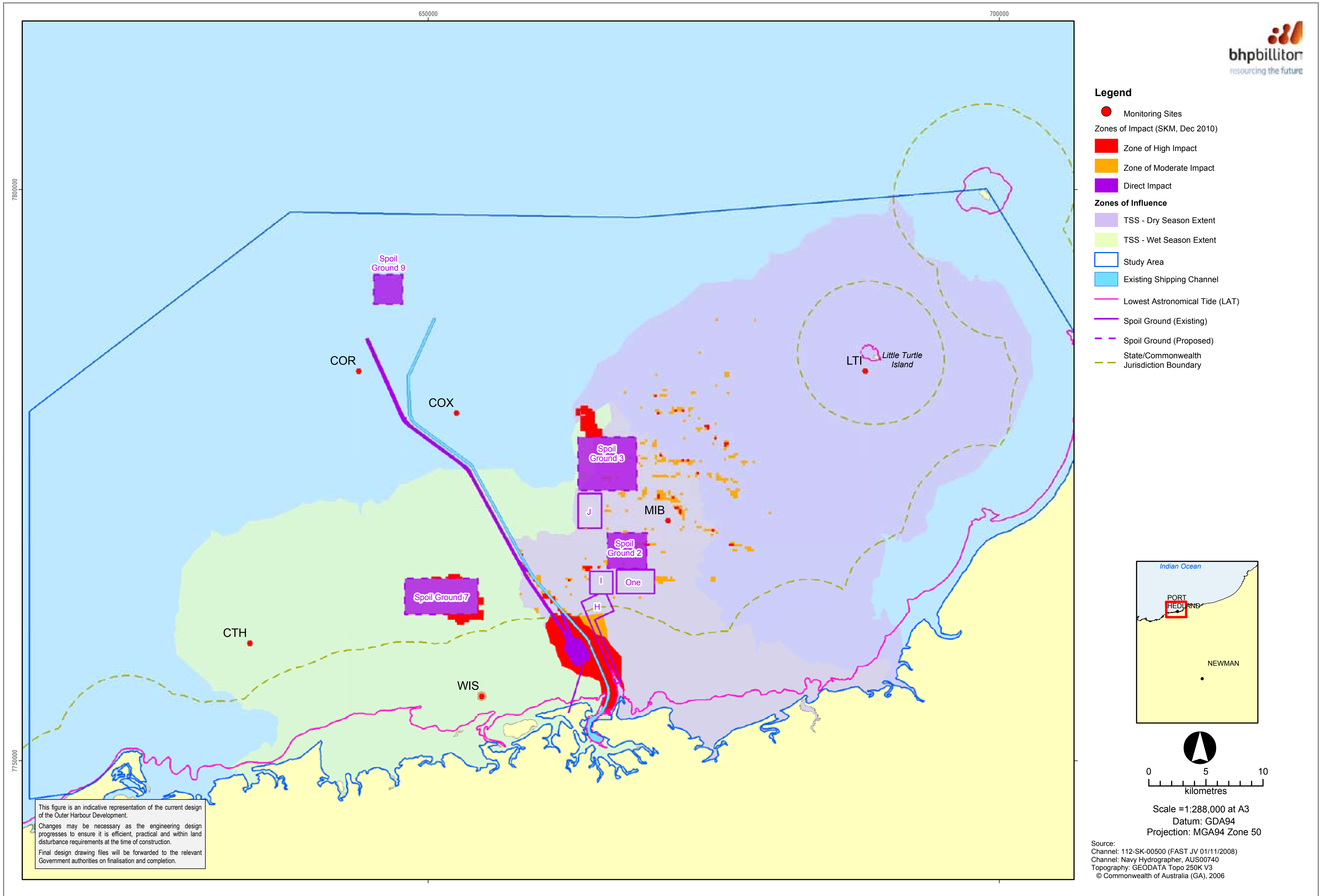

Figure 10.25 Zones of Impact for the Proposed Outer Harbour Development

LAU	Historical Loss (ha)
8	14.53
Port Hedland	2.17

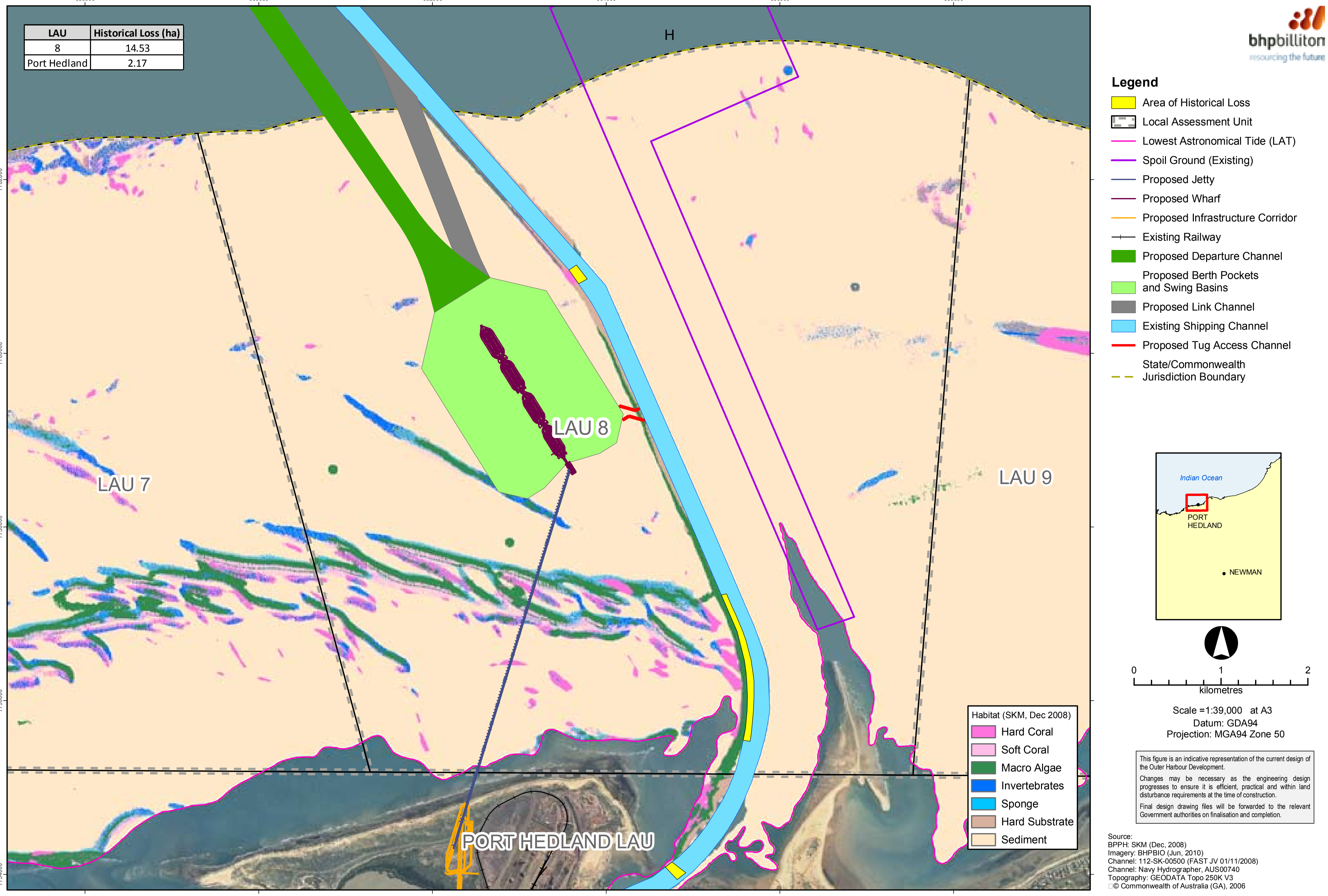

Figure 10.26 Historical Subtidal BPPH Loss in State Waters

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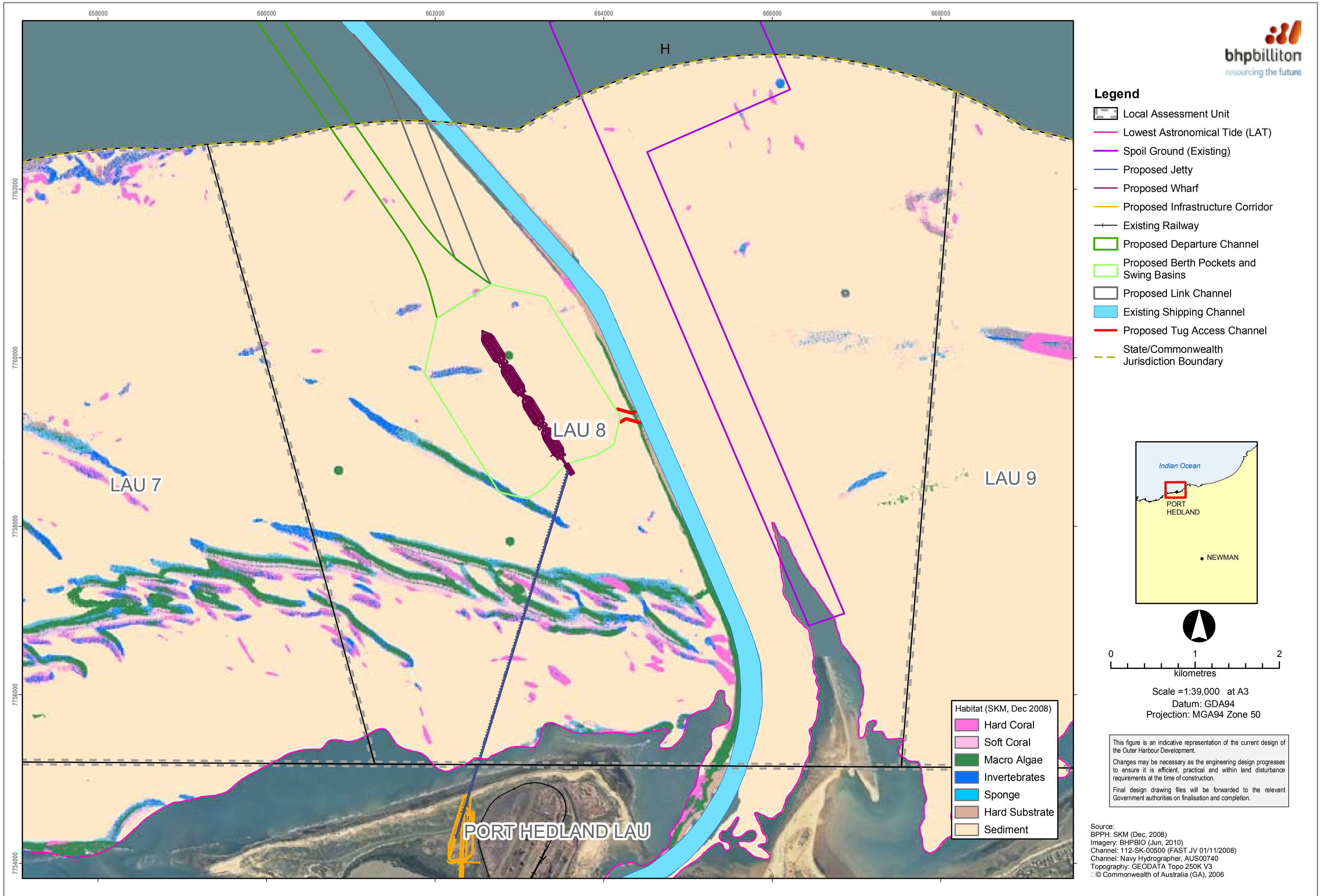

Figure 10.27 Direct Losses of Subtidal BPPH in State Waters due to the Proposed Outer Harbour Development Marine Infrastructure Footprint

As a result, indirect losses of BPPH are predicted to occur in the Zone of High Impact due to both low light conditions and elevated sedimentation rates. Largely, these environmental conditions will be spatially coincident (i.e. losses due to low light and high sedimentation will both lead to BPPH losses in any one area, rather than one or the other being the main impact driver). The environmental benefit arising from these unique conditions is that the indirect losses from sedimentation and turbidity are relatively small spatially and therefore the total benthic area predicted to be affected is also relatively small in context of the total size of the proposed Outer Harbour Development.

Indirect and irreversible loss of BPPH is predicted to occur in LAU 8, within which the Zone of High Impact lies, due to elevated sedimentation rates associated with the proposed Outer Harbour Development construction dredging activities. The area of BPPH predicted to be lost due to the indirect impact of sedimentation is 140.3 ha (45.6%) (**Table 10.24**). **Figure 10.28** illustrates the predicted irreversible losses of BPPH in LAU 8 due to elevated sedimentation rates.

Cumulative Losses

A summary of the historical loss estimated for the region (19.2 ha), direct loss predicted for removal during construction of the marine infrastructure (7.6 ha), and irreversible indirect loss predicted to occur due to elevated sedimentation rates (140.3 ha), is provided in **Table 10.25**. From these loss components, the total cumulative loss of subtidal BPPH in State waters is 162.9 ha, with resultant percentage losses of 52.9% in LAU 8 and 2.2% in Port Hedland Industrial LAU.

A breakdown of the subtidal BPPH loss predicted in State waters into BPP and non BPP categories is provided in **Table 10.26**. Of the total 147.9 ha of BPPH loss associated with the proposed Outer Harbour Development, 5.1 ha of that area is habitat without benthic communities present, while macroalgae (60.8 ha or 41.1%) and sponges (28.8 ha or 19.5%) collectively represent the largest component of the benthic community.

Table 10.26 – BPP and Non BPP Categories Included in the Subtidal BPPH Loss Estimates for the Proposed Outer Harbour Development

Benthic Category	Area (ha)
Benthic Primary Producers	
Macroalgae	60.8
Hard Corals	22.3
Non Benthic Primary Producers	
Soft Corals	5.2
Sponges	28.8
Other (includes sessile invertebrates	25.7
No Benthic Communities Present	5.1
Total	**147.9**

In summary, the total cumulative loss of BPPH occurring in the Zone of High Impact within State waters is estimated at 167 ha. In summary, the total cumulative losses attributable to the proposed Outer Harbour Development are 167.1 ha (52.9% in LAU 8). Although described as a mosaic or mixed assemblage benthic community, the predominant organisms supported by this BPPH are macroalgae and sponges. No direct or indirect losses to seagrasses are predicted as no seagrasses have been observed within the Zone of High Impact.

Table 10.24 – Predicted Indirect Losses of Subtidal BPPH due to Dredge-Related Sedimentation

LAU	Total Area of BPPH (ha)	Proposed Loss due to Sedimentation (ha)	Total Loss (ha)	Total Loss (%)	EPA Category and Loss Threshold
LAU 8	308	140.3	140.3	45.6	E – 10%

Table 10.25 – Total Cumulative Losses of Subtidal BPPH due to the Proposed Outer Harbour Development

LAU	Total Area of BPPH (ha)	Historical Loss (ha)	Direct Loss (ha)	Indirect Loss (ha)	Total Loss (ha)	Total Loss (%)	EPA Category and Loss Threshold
LAU 8	308.0	15.0	7.6	140.3	162.9	52.9	E – 10%
Port Hedland Industrial LAU	190.07	4.17	–	–	4.17	2.2	E – 10%
Totals	**498.07**	**19.17**	**7.6**	**140.3**	**167.07**	**...**	

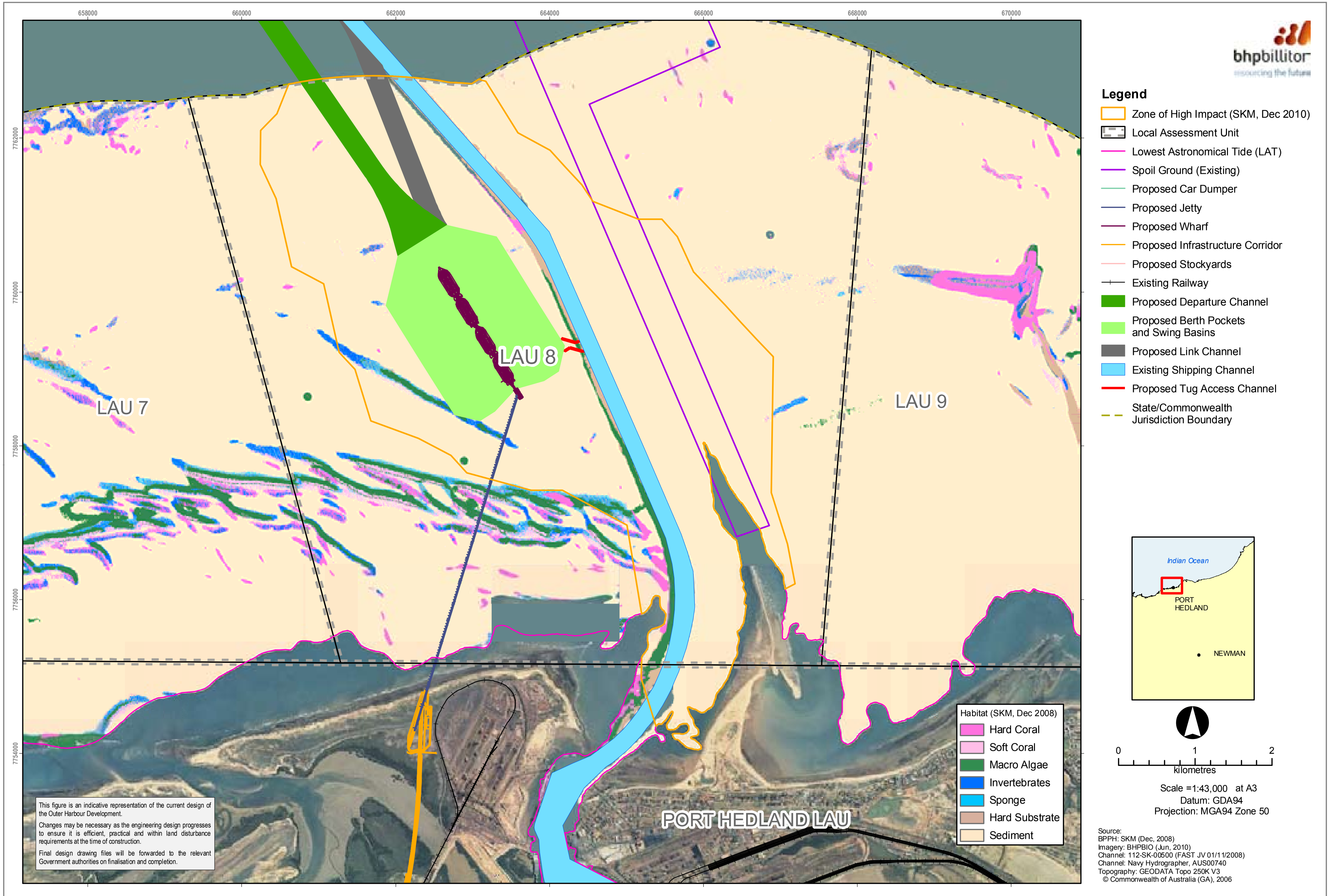

Figure 10.28 Predicted Irreversible Losses of Subtidal BPPH due to Elevated Sedimentation Rates

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Indirect Impacts in the Zone of Moderate Impact

Water quality conditions in the Zone of Moderate Impact will include elevated concentrations of sediment particles in suspension (i.e. increased TSS concentrations) and, where calmer water conditions are experienced, the particles in suspension will settle out resulting in elevated sedimentation rates. Daily cycles of settlement and resuspension of deposited sediments in the Zone of Moderate Impact are likely to occur due to the strong tides and influence of waves. It is this thinner layer of sediments, deposited, resuspended and dispersed on a daily basis that is the driver of indirect impacts in this impact zone.

BPPs observed to be present at some time during the year within the Zone of Moderate Impact are hard corals and macroalgae. The nearest seagrasses are some 10 km to the south west of the boundary of the Zone of Moderate Impact and lie within the Zone of Influence. 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 Zone of Moderate Impact to photosynthesise. It is due to this regular opportunity to photosynthesise that no irreversible losses due to turbidity and sedimentation are predicted for BPPs in the areas demarcated by the Zone of Moderate Impact.

Elevated suspended solids in the water column and increased sedimentation rates have the potential to impede filter feeding activity of non-BPPs with an overload of suspended material. For example, mussels under such conditions may close up and avoid feeding until improved conditions return. When the water quality perturbation occurs over extended durations (e.g. days) this can reduce the feeding opportunities that mussels would otherwise undertake. For sponges that do not have the opportunity to shut down under such conditions, an overload of filtered material would result. However, the nature of the increase in suspended material and sedimentation rates is such that primarily fine particles will be resuspended and redistributed on at least a twice daily basis. As such, sessile invertebrates comprising the majority of the non-BPP community will have a period of respite during the change of tide when material will be lifted and moved relieving any sedimentary cover they are experiencing, and during slack tides the concentration of suspended material will temporarily reduce. It is this daily dynamicity in suspended solid concentrations and sedimentation conditions that will allow non-BPPs to survive within the Zone of Moderate Impact.

Zone of Influence

Field investigations by SKM reported a sparsely inhabited area (approximately 5 m x 5 m area of *Halophila decipiens*) offshore of Weerdee Island (**Section 6.6.2**). In addition, a small and sparse stand of *Halophila ovalis* was observed at North Turtle Island. The most extensive seagrass community was found in the shallow protected embayment between Weerdee and Downes Islands, to the west of Finucane Island. This community was predominantly *Halophila ovalis* and the seagrass was mapped to cover approximately 86 ha or 4.8% of the embayment in beds of sparse (5 to 25% cover) to medium (25 to 50% cover) density. Mixed assemblages were most commonly present in this area with macroalgae and occasionally sponges (SKM 2009d).

These areas of seagrass were identified after exhaustive field investigations including 734 field activities undertaken across the project area (refer **to Section 6.6.2**). Given the field effort undertaken, and the temporal breadth of these studies, it is likely that the distribution of seagrass throughout the Port Hedland region is spatially and temporally dynamic. In addition, it appears that seagrasses in the area are preferentially located in areas that offer shelter from prevailing metocean conditions (e.g. in the lee of islands).

The nearest seagrasses are some 10 km to the south west of the boundary of the Zone of Moderate Impact and lie within the Zone of Influence and no losses or indirect impacts are predicted for benthic communities or their habitats found within the Zone of Influence.

10.3.4.3 Commonwealth Subtidal Habitats

Loss of benthic habitats within Commonwealth marine areas will occur due to direct removal during construction of the proposed marine infrastructure and from smothering due to spoil disposal. Each of these benthic habitat loss aspects is considered below. In addition, assessment of potential impacts to coral spawning is provided.

Direct Impacts

Marine Infrastructure

Dredging of the channel will result in the removal of 64.2 ha of BPPH. The existing substrate in the areas of the proposed channel and turning basin is predominantly sand, although the footprint does intersect hard substrate in some areas, resulting in the loss of benthic habitat (**Table 10.28**). The greater proportion of benthic habitat affected by the proposed channel is at the very outer end of the channel, amounting to 6.8 ha or 10.5% of the loss associated with the proposed channel.

The majority of the proposed channel has been aligned to follow the deepest areas between the limestone ridgelines thereby largely avoiding hard substrate BPPH. The channel alignment has been located over areas mainly comprising bare sandy habitat. The channel does however intersect limestone substrate near the channel entrance. The benthic community at this location is a mosaic comprising hard and soft corals, sponges and macroalgae (**Figure 10.29**). These benthic organisms and the type of community they comprise are well represented throughout the Port Hedland region.

Spoil Disposal

Smothering of the seabed resulting from dumping of dredged material into the disposal grounds will result in the loss of subtidal habitat. Loss of subtidal habitat supporting benthic communities due to spoil disposal has been minimised by the placement of the proposed spoil grounds on areas predominantly comprised of sandy substrate (**Table 10.27**). This is reflected in the very low total hard substrate areas that will be affected by spoil disposal: the total hard substrate area that will be smothered in Spoil Grounds 3 (8.3 ha), 7 (0 ha) and 9 (7.8 ha) amounts to 16.1 ha, or 0.3% of the total area (5,058.3 ha) proposed for spoil disposal.

Indirect Impacts

Sediment plume modelling indicates that increased turbidity will be generated during offshore disposal of dredged material into the proposed spoil grounds (refer to **Figure 10.12**, **Figure 10.13** and **Figure 10.14** of **Section 10.2**). Modelling indicates that while finer fractions of the spoil material are likely to disperse rapidly due primarily to tidal influence, the larger fractions of dredged material will fall out of the water column and accumulate on the sea floor. It is predicted that these larger fractions of suspended material will settle between each disposal episode (approximately four to five hours). As such, due to the batch disposal methods to be employed (by barge), there is not likely to be cumulative increases in turbidity over time caused by subsequent disposal episodes.

Coral Spawning

A number of hard coral species have been recorded within marine areas of State and Commonwealth jurisdictions, with the greatest diversity and coverage of hard corals occurring in Commonwealth waters. Genera described as dominant or sub-dominant in benthic communities include *Turbinaria*, *Acropora*, *Favites* and *Montipora* (refer **Section 6.6.2**). Hard corals reproduce by releasing reproductive propagules (larvae, eggs or sperm) into the water column. Some hard corals have the reproductive strategy of mass spawning by which ejection of propagules by a large number of individuals within the community occurs concurrently over a number of consecutive nights during one period of the year. Although this reproductive strategy improves the odds of successful fertilisation, the singular nature of the reproductive event makes the coral community susceptible to simultaneous environmental perturbations including altered water quality due to dredging.

Suspended solids in the water column can interrupt successful fertilisation of coral reproductive propagules. Recent studies into the effect of suspended solids (grain size less than 63 μm) on fertilisation and larval development in *Acropora millepora* concluded that suspended sediment levels greater than 50 mg/L inhibited fertilisation but had little effect on larval development (Humphrey *et al.* 2008). The suspended sediments are likely to exhibit a range of sizes. A more applicable study into the effects of suspended solids on fertilisation and larval development that incorporated a larger range of grain sizes from 50–200 μm found that suspended sediments concentration of greater than 50 mg/L is required to inhibit fertilisation but had little effect on the larval development (Gilmour 1999).

Although corals within the Pilbara region are more tolerant of suspended solids concentrations than species found elsewhere in extremely low turbidity environments, substantial increases in TSS concentrations may impact on successful fertilisation

Table 10.27 – Areas (ha) and Proportions (%) of Substrate Types Present within the Proposed Outer Harbour Development Spoil Grounds

Substrate Type	Spoil Ground 2*	Spoil Ground 3	Spoil Ground 7	Spoil Ground 9
Total area	1,092.8 ha	2,406.3 ha	2,002.3 ha	649.7 ha
Hard substrate	11.3 ha	8.3 ha	0 ha	7.8 ha
	1.03%	0.4%	0%	1.2%
Sediment	1,081.5 ha	2,398 ha	2,002.3 ha	641.7 ha
	98.97%	99.6%	100%	98.8%

Note: the proportions do not sum 100% due to a small amount of overlap attributable to the mosaic nature of benthic habitats.
** Spoil Ground 2 is proposed only for contingency and therefore the areas presented are for information only and not proposed as losses.*

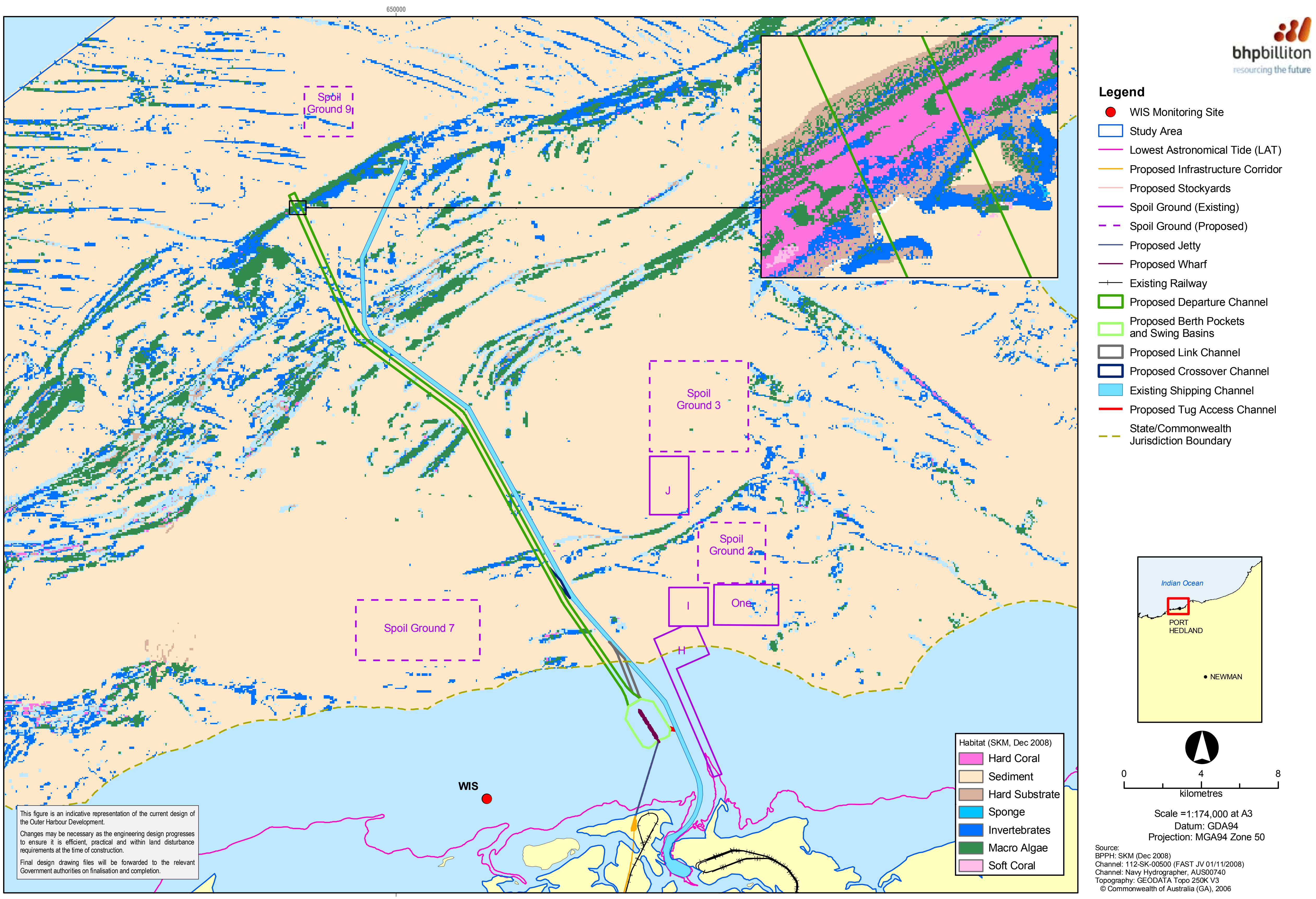

Figure 10.29 Commonwealth Subtidal Habitats within the Proposed Outer Harbour Development Marine Infrastructure Footprint

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and subsequent community recruitment. Given the proposed dredging program is for an extended period (five years comprising 56 discontinuous months of dredging), there is a risk that coral community reproduction and recruitment will be adversely impacted.

Monitoring of the timing of spawning for hard corals in the project area found that although the dominant and sub-dominant community corals primarily spawn in either spring (e.g. *Acropora* and *Monitpora*) or autumn (e.g. *Turbinaria* and *Favites*), these genera also appear to spawn in the alternative window to some degree. As such, a singular mass spawning by the coral community in the Port Hedland region is not believed to occur.

The behaviour of the sediment is strongly influenced by tides and wave energy. As a consequence the sediment plume is predicted to shift seasonally (refer **Section 10.2.4**) resulting in benthic habitats experiencing altered water quality due to dredging activities for a portion of the year, after which the altered water quality conditions will subside. With respect to hard coral spawning, this offers some part of the benthic community occurring inside the project area the opportunity to successfully spawn each year. In turn, successful recruitment to the hard coral community can continue throughout the proposed construction program meaning there is no definable key critical window during which dredging activities need to be suspended.

In addition to the hard coral communities within the proposed project area, the limestone ridgelines that feature so strongly within the area are contiguous beyond the development area. The continuity of this benthic structure and associated habitat further reduces the risk of reduced or failed recruitment for hard corals in the region.

For further information on coral spawning please refer to **Appendices B32** and **B33**.

Summary of Predicted Impacts

In summary, impacts to marine habitats resulting from the proposed Outer Harbour Development are predicted as follows:

- **Onshore Intertidal Habitats**: direct loss of 27.0 ha of mangroves, primarily within *Avicennia marina* (scattered; 11.0 ha) and *A. marina* (closed canopy, landward edge; 7.0 ha) habitat;
- **Coastal Intertidal Habitats**: direct loss of 1.7 ha of intertidal platform mostly bare rock in the upper intertidal zone;
- **State Subtidal Habitats**: direct loss of 147.9 ha of BPPH, of which the predominant organisms supported by this BPPH are macroalgae and sponges. No losses or impacts to seagrasses are proposed or predicted; and
- **Commonwealth Subtidal Habitats**: direct loss of 80.3 ha of BPPH due to the channel and turning basin and spoil ground disposal areas.

A summary of the total proposed and predicted losses of marine habitats for State and Commonwealth jurisdictions is provided in **Table 10.28**.

10.3.5 Management Measures

Various marine habitats will be lost as a result of the construction of infrastructure and dredging activities for the proposed Outer Harbour Development. Included in the marine habitat impacts are direct removal of mangroves and subtidal hard substrate supporting mixed assemblages of BPPs and non BPPs that occur within the project footprint. In addition, indirect loss of coastal intertidal and subtidal BPPH due elevated turbidity and sedimentation is predicted. These potential impacts will be managed via proposed avoidance, mitigation, monitoring and contingency measures. The management measures applicable to impacts to marine habitats arising from construction of the proposed Outer Harbour Development are summarised in **Table 10.29**.

As part of the environmental assessment process for the Outer Harbour Development, BHP Billiton Iron Ore has reviewed available dredging technology to minimise potential impacts to the marine environment from the dredging and spoil disposal activities.

A key part of the process to optimise the dredging works has been the early engagement of the dredging contractor. The selected dredging contractor is a world leader in the dredging and marine engineering industry and has extensive experience in the implementation of dredging projects in environmental sensitive areas including Western Australia. Importantly, the selected dredging contractor has been extensively consulted with respect to the techniques and technologies available to minimise turbidity related impacts. The selected dredging contractor operates a modern dredging fleet equipped with state of the art dredging equipment including monitoring systems that monitor and optimise the dredging' operations.

Table 10.28 – Summary of Habitat Losses in State and Commonwealth Jurisdictions due to the Proposed Outer Harbour Development

Habitat Type	Total Area (ha)	State (ha)				Common-wealth (ha)	Loss (ha)
		Inside PHI LAU	Loss	Outside PHI LAU	Loss		
Onshore Intertidal							
Mangroves	2,389	2,389	27.0	–	–	–	
Samphire	Under study	Under study	–	–	–	–	
Cyanobacterial mats	Under study	Under study	–	–	–	–	
Coastal Intertidal							
Sediment	20,820	3,782	–	17,038	–	–	–
Mixed assemblage	1,364	429	1.7	935	–	–	–
Mangroves	116.0	–	–	116	–	–	–
Subtidal							
Hard substrate	363,442	898	–	5,220	7.6	35,531	80.3
Sediment			–	79,591	5.1	242,203	5,042
Hard coral	18,086	0.48	–	4,937	22.3	13,148	–
Macroalgae	16,026	162	–	3,083	60.8	12,781	–
Seagrass	86.0	–	–	86	–	–	–
Soft coral	3,400	0.33	–	733	5.2	2,667	–
Sponges	8,000	11.10	–	1,521	28.8	6,469	–
Sessile invertebrates	20,275	–	–	2,823	25.7	17,452	–

The dredgers that will be utilised on the proposed Outer Harbour Development have the following technology that will minimise the risk of dredging related turbidity impacts:

- Differential Geographic Positioning System (DGPS) equipment to improve the accuracy of the dredging and spoil disposal operations;
- Online visualisation of the dredging operations including drag head / cutter head location, pump speeds, mixture densities, dredge production and tidal information to optimise the dredging operations;
- An anti turbidity (green valve) on the TSHDs to limit the intensity and spatial extent of the turbidity plume;
- Under water pumps of the CSD to increase dredging efficiency and reduce the duration of the dredging operations; and
- Multi-beam hydrographical survey equipment to provide rapid and accurate updates of seabed heights to help minimise over-dredging.

The dredging vessels that will be utilised have been selected with the environmental performance of the project as a key consideration. Specifically:

- Smaller TSHDs with lower drafts will be used to dredge shallow areas which will minimise the creation of turbidity via propeller wash;
- Dredging in the deeper waters will be undertaken by large TSHDs which will minimise the duration of the project and reduce the temporal extent of potential impacts;
- The use of larger, more powerful TSHDs will reduce the requirement for pre-treatment of material (crushing by the CSD) which will minimise rehandling requirements and intensity and duration of the turbidity related impacts; and
- The use of large CSDs to dredge the consolidated material will minimise the risk that pre treatment of the material by drilling and blasting will be required (note – drilling and blasting is not currently envisage as being required).

Furthermore, following completion of geotechnical testing, BHP Billiton Iron Ore will incorporate the data into refining and optimising the dredging programme. The data will also be incorporated into detailed engineering and marine infrastructure design. BHP Billiton Iron Ore propose to remodel the dredging and disposal impacts and the results will inform the Dredge Spoil Disposal Management and Monitoring Plan. This modelling will include scenarios that incorporate management measures such as reducing overflow and temporarily moving the dredge to alternative locations, or disposal at the proposed contingency spoil grounds. This information will be included in the Final PER/EIS.

Impacts to marine habitats will be managed primarily through measures and controls as detailed in the Mangrove Management Plan (MMP) (**Appendix A2**) and the Dredge Spoil Disposal Management and Monitoring Plan (**Appendix A3**). In accordance with the hierarchy of controls, the direct removal of significant marine habitat has been minimised during the concept design stage. The objective of the marine habitat management measures and associated monitoring program is to ensure that indirect impacts on significant marine habitat are minimised and that contingency measures are implemented in the event that indirect impacts are not held within acceptable levels.

Key management measures proposed within these plans include:

- the proposed channel alignment is designed to mirror the existing Port Hedland shipping channel except where operational requirements do not allow this;
- the amount of dredging to be undertaken will be minimised;
- spoil grounds will be located in large sandy areas away from limestone ridge lines where populated benthic habitat has been mapped;
- management checks will be established to ensure that disposal of dredge spoil occurs within the approved spoil ground footprints;
- the jetty abutment structure will be designed and located to minimise as much as practicable the removal of BPPH; and
- West Creek crossing will be designed such that the impact to tidal/drainage patterns is minimised.

Benthic habitat surveys will be undertaken in the coastal intertidal and State subtidal areas prior to commencement of dredging activity to further inform the implementation of these management plans. Surveys will determine the seasonal and spatial variability in marine habitats in these areas, and the environmental conditions under which they exist. Surveys will be conducted over at least a 12 month period with a minimum frequency of three monthly. An important output of the survey will be baseline marine habitat data that may be used as a temporal reference for areas that may be exposed to altered water quality conditions during dredging and construction activities.

In addition, post-completion surveys of areas proposed for direct losses of mangrove and subtidal habitats will be undertaken to confirm that losses did not exceed the predicted extents.

10.3.6 Significance of Residual Impact

The extensive and comprehensive nature of the benthic habitat surveys and resultant habitat maps provide a sound basis to determine habitat impacts arising from the proposed development activities.

The estimated losses and impacts of marine habitats due to the proposed Outer Harbour Development are not extensive in a regional context. The relatively low areas of habitat loss are a function of the harsh environments in which the marine habitats occur, a driver of habitat distribution and resultant ecosystem value. Onshore, extremely low rainfall conditions generate stressful conditions for mangroves and other intertidal BPPH, resulting in low species numbers and constrained, low density distributions. Offshore, macrotidal and exposed conditions result in extensive plains of sand, silt and rubble with occasional relief offered to benthic organisms by raised limestone ridgelines or the lee of coastal islands. As a consequence the marine environment is largely sand (86% of the marine study area).

Although losses of marine habitat are anticipated with the proposed Outer Harbour Development, all habitats that will be affected are well represented in the Pilbara region and none support species that are exclusively dependent on the habitats that will be affected.

Onshore Intertidal Habitats

- The mangrove vegetation associations, salt marsh and cyanobacterial mats present in the area within and adjacent to the proposed corridor to Finucane Island are not unusual, and are representative of the broad vegetation associations recorded throughout the harbour and the wider Pilbara region.
- A comparative assessment of the relative value of each BPP concluded that the mangrove areas are the key component providing major inputs into the support of ecosystem function within the Port Hedland Industrial Area LAU. Although the forecast loss associated with the proposed Outer Harbour Development include stands of high value mangrove vegetation, the loss is not considered to pose a threat to the ecological functions of these mangrove vegetation associations which are widespread in the harbour and elsewhere in the Pilbara region.
- Although the proposed causeway over West Creek may indirectly impact onshore marine habitats, the use of culverts will maintain tidal exchange and greatly reduce the likelihood and scale of any potential impact. Any residual indirect impacts to marine habitats

that may occur as a result of altered tidal regimes are likely to be minimal and will not affect ecosystem function. In addition, this intertidal marine habitat is not important for any rare or threatened species and is well represented elsewhere in the region.

Coastal Intertidal Habitats

- The direct loss of coastal intertidal BPPH associated with the marine infrastructure represents a very small fraction of the total BPPH of this type in the Port Hedland region.

Subtidal Habitats

- The species richness of coral taxa recorded at baseline monitoring sites is very low in comparison to other areas within the Pilbara region. Based on the low species richness, abundance of hard corals and dominance of the species Turbinaria, coral communities that inhabit subtidal habitats in the Port Hedland region can be described as predominantly high turbidity (low light), sedimentation adapted communities.
- There is little evidence of carbonate accretion onto the tops of the limestone ridges in this area on which hard coral communities grow. The low percentage hard coral cover and lack of carbonate accretion on the ridges, implies that the turnover rate of the coral communities in this area is very high. This is most likely due to the extreme metocean conditions the coral communities experience during the seasonal storms and frequent cyclones.
- The LiDAR mapping indicates that the limestone ridgelines extend along the entire extent of the coastline, from North Turtle Island in the north-east to beyond Cape Thouin in the south-west. Navigational chart data suggest that these ridgelines extend well beyond the extent of the LiDAR mapping undertaken for this project. Based on this information, this area could be defined as one uniform ecosystem stretching for hundreds of kilometres.
- Field observations found the available BPPH to be very sparsely distributed within the project footprint and spoil ground areas, as well as across the broader investigative area. The lack of substantial areas of BPPH and the low densities of benthic primary producers on the available BPPH within the project footprint suggest the direct losses due to removal of seabed and smothering will not significantly affect the ecosystem functions where these losses will occur.

10.3.7 Predicted Environmental Outcomes

The predicted environmental outcomes for marine habitats as a result of the proposed Outer Harbour Development are:

State

- No more than 27.0 ha of mangrove habitat, or a total cumulative loss of 5.7%, in the Port Hedland Industrial LAU will be lost.
- No more than 1.7 ha of coastal intertidal BPPH, or a total cumulative loss of 14.2% in the Port Hedland Industrial LAU, will be lost.
- No more than 147.9 ha of subtidal BPPH, or a total cumulative loss of 52% in LAU 8, will be lost.

Commonwealth

- No more than 80.3 ha of hard substrate benthic habitat due to the marine infrastructure and spoil ground disposal areas will be lost.
- Loss of marine habitats is not predicted to result in impacts to marine fauna listed under the EPBC Act.

Table 10.29 – Summary of Potential Impacts and Management Actions Associated with Marine Habitat

Environmental Aspect	Source	Impacts	Management
Seabed disturbance	Dredge and spoil disposal	Direct removal of subtidal BPPs and BPPH due to dredging.	*Avoidance/Mitigation/Management Measures:* ▸ the proposed channel alignment will be designed to mirror the existing Port Hedland shipping channel. ▸ The volume of dredging to be undertaken will be minimised. *Monitoring:* ▸ Monthly bathymetric surveys demonstrating dredging and spoil disposal has been undertaken within the approved project footprint. ▸ Monitoring will be undertaken to determine the total amount of benthic community and BPPH losses in the Zones of High and Moderate Impact in pre and post-dredging surveys.
		Smothering mortality of subtidal BPPs and BPPH due to disposal.	*Avoidance/Mitigation/Management Measures:* ▸ Spoil grounds are located in large sandy areas away from limestone ridge lines where benthic primary producer habitat has been mapped. ▸ Management checks will be established to ensure that disposal of dredge spoil occurs within the approved spoil ground footprints. ▸ All vessels will include features such as on-line visualisation of bathymetric charts, loading diagrams, production statistics and vessel movements. *Monitoring:* ▸ Surveyed dredged quantities (net measured in situ prior to dumping) will be recorded daily and compared to the approved disposal quantities. ▸ A bathymetric survey of each spoil ground used will be undertaken within one month and again within 12 months of the completion of all disposal activities authorised under the Sea Dumping Permit. A digital copy of each of the bathymetric surveys will be provided to the RAN Hydrographer. ▸ Operational dredging logs showing the time and location of each disposal event will be maintained. ▸ Coral health monitoring will be undertaken to determine the total amount of hard coral benthic primary producer habitat and benthic primary producer losses in the areas of potential impact in pre and post-dredging surveys. *Contingency Measures:* ▸ An adaptive approach which includes identification of alternative spoil ground and dredge areas if impacts at a particular location exceed impact triggers will be implemented.
		Indirect impacts to subtidal BPPs and BPPH from dredging and disposal activities (sedimentation and light deprivation). Sub-lethal affects on reproduction success of coral spawning.	*Avoidance/Mitigation/Management Measures:* ▸ A green valve will be used within the hopper overflow pipe of each TSHD. The green valve works by reducing the entrainment of air within the overflow water and, minimises the turbulence (air) in the water column after the overflow water is released back into the marine environment. As a result, the spatial and temporal extent of the dredging plume is reduced. ▸ During sediment transport by the TSHD, the level of the overflow pipe will be raised to its highest point to ensure minimum spillage. ▸ Hopper door seals will be maintained in good condition to ensure minimum loss of material during transport. ▸ Within operational constraints, sailing routes to the disposal areas will be planned to minimise propeller wash (for example, utilisation of the channel where possible ▸ Hopper dewatering will be confined to areas away from sensitive receptors and where practical will only occurring within the dredging and spoil disposal areas ▸ Well maintained dredging vessels and properly calibrated equipment will be used. ▸ Dredging vessels will include features such as on-line visualisation of bathymetric charts, loading diagrams, production statistics and vessel movement.

Table 10.29 – Summary of Potential Impacts and Management Actions Associated with Marine Habitat (continued)

Environmental Aspect	Source	Impacts	Management
			Monitoring: ► A reactive water quality monitoring program will be implemented to effectively manage impacts within the limit of allowable loss during the dredging period in the project area (detail provided in the DSDMP (Appendix A3)). ► A tiered trigger level approach will be applied to the Zones of Impact and Influence, whereby the exceedance of each subsequent level would result in a greater degree of monitoring and/or management (detail provided in the DSDMP (**Appendix A3**)).
	Construction of marine facilities	Direct removal of subtidal BPPs and BPPH underneath the abutment portion of the jetty.	*Avoidance/Mitigation/Management Measures:* ► Jetty and abutment structure will be designed and located to minimise as much as practicable the removal of BPPH. ► Clear briefings and instructions will be provided to contractors regarding the procedures to be undertaken to prevent disturbance outside the proposed footprint. *Monitoring:* ► BPPH mapping: satellite imagery and field surveys will be used to map the distribution and coverage of the intertidal communities situated near the project footprint. BPPH mapping will be undertaken prior to the commencement of the project and at the end of each development stage including project completion.
		Direct removal of intertidal BPPs from establishment of infrastructure corridor across West Creek.	*Avoidance/Mitigation/Management Measures:* ► West Creek crossing will be designed such that the impact to tidal/drainage patterns is minimised. ► Coloured flagging tape (where practical) will be used to clearly define the mangrove disturbance envelope. ► Clear briefings and instructions to contractors will be provided regarding the procedures to be undertaken to prevent disturbance outside of the approved project footprint. ► Mangroves and other vegetation will be removed using both land based and floating equipment where appropriate, access paths will be minimised through the mangroves and will not disturb outside the approved project footprint. ► Construction machinery will remain within the approved project footprint to ensure that there are no unplanned losses or damage of adjacent areas of mangrove. ► Where the proposed conveyor corridor traverses existing channels within the mangrove habitat, culverts will be installed to maintain tidal flows to the area. ► Any fill to the base of the conveyor, road and causeway structures will be stabilised to prevent washout and erosion. *Monitoring:* ► Mangrove mapping: aerial photography and field surveys will be used to map the distribution and coverage of the mangrove communities situated near the project footprint. Aerial photography will be orthorectified and will allow for the calculation of mangrove cover. Mangrove mapping will be undertaken prior to commencement of the project and at project completion. ► Mangrove health: surveys including regular visual assessments for mangrove condition and detailed mangrove health surveys will be undertaken prior to commencement of construction, after six months and on completion of construction activities. ► Sedimentation monitoring will be undertaken at the same sites and frequency as the mangrove health visual assessments. *Contingency Measures:* ► Clearing activities will be temporarily stopped until the outcomes of an investigation into the non-approved clearing have been concluded.

Table 10.29 – Summary of Potential Impacts and Management Actions Associated with Marine Habitat (continued)

Environmental Aspect	Source	Impacts	Management
Physical presence	Permanent marine infrastructure (West Creek crossing)	Indirect impacts to intertidal BPPs (mangroves) from alteration of tidal/ drainage patterns	*Avoidance/Mitigation/Management Measures:* ▸ Design of the West Creek crossing such that the impact to tidal/drainage patterns is minimised.

10.4 Key Factor – Marine Fauna

The following sub-sections present the assessment of impacts on marine fauna associated with the proposed Outer Harbour Development, incorporating design modifications, mitigation and management measures applied to manage predicted impacts.

10.4.1 Management Objective

The management objectives that will be applied to the project for the environmental factor, marine fauna are to:

- maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through avoidance or management of adverse impacts and improvement in knowledge;
- provide for the protection of the environment, especially Matters of National Environmental Significance and to conserve Australian biodiversity; and
- be consistent with all relevant legislation and guidelines.

10.4.2 Description of Factor

The description of the existing marine fauna of significance in the project area, which is presented in **Section 6.6**, is based on information gathered through desktop reviews and field surveys. Relevant key findings include:

- **Turtles**: Green and Flatback Turtles, both of which are listed as vulnerable under the EPBC Act, use the Port Hedland area for foraging. The nearest known turtle nesting sites are at Cemetery Beach located over 5 km from the proposed dredging location and breeding females use the waters of the project area for inter-nesting (Pendoley Environmental 2009a);
- **Mammals**: Humpback Whales, listed as vulnerable under the EPBC Act, may be encountered during their northern migration to breeding grounds in late June to early August, and southern migration (with calves) during late August to mid October. However, the Port Hedland area does not support calving, aggregation or feeding areas (NHT 2005). The Spotted Bottlenose Dolphin and Dugong, listed as migratory species under the EPBC Act are also found in the project area, although no resident populations are known to occur (Prince 2001). The Port Hedland region is not an area featuring extensive seagrass meadows: of the 49,685 ha represented by the proposed Outer Harbour Development, only 86 ha of seagrass has been recorded during the four years and over 700 survey points investigated; and
- **Fish**: the fish species of the Port Hedland region have not been well surveyed although they are expected to include a sub-set of the fish recorded at the Dampier Archipelago approximately 250 km to the west. Surveys of the Dampier Archipelago have recorded a total of 650 fish species consisting of a rich 465 coral reef species, 116 mangrove associated species, 106 species associated with soft bottom habitat and 67 pelagic species (Hutchins 2004). Potentially occurring species listed as "marine species" under the EPBC Act include 28 species of pipefish and five species of seahorse. Three species of Sawfish may occur in the area and are listed as vulnerable under the EPBC Act. As well, the Whale Shark occurs in offshore waters and is listed as vulnerable under the EPBC Act.

10.4.3 Assessment Guidance

Guidance on the assessment of impacts on marine fauna exists at State and Commonwealth government levels. A summary of the assessment guidance documents relating to marine fauna considered in this impact assessment is provided in **Table 10.30**.

The EPBC Act and EAGs outline the framework for assessment of marine fauna at Commonwealth and State levels. All native Australian marine fauna, as well as those that periodically migrate to Australia are protected in Western Australia under the WC Act. Under this Act, it is an offence to kill, capture, disturb, molest or hunt any protected or threatened fauna. The level of protection for a given species depends on its conservation status. Species requiring special protection are listed under one of the following four categories in the Wildlife Conservation Notice:

- 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 agreement between the governments of Australia and Japan relating to the protection of migratory birds and birds in danger of extinction (i.e. Japan Australia Migratory Bird Agreement (JAMBA)); and
- Schedule 4 – other specially protected fauna.

EPA Guidance Statement No. 8 (EPA 2007) stipulates a precautionary approach should be adopted in the assessment of potential impacts of noise and vibration on marine fauna. It initially requires the proponent to identify whether there is a population which may be at risk of noise impacts because of their need to hear signals clearly over ambient noise; their inability to escape from the noise; or their endangered status. The second stage of this process requires a risk assessment to be carried out to estimate the likelihood of adverse impacts.

Table 10.30 – Legislation and Assessment Guidance relating to Marine Fauna

Document	Description
Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth Govt)	Addresses the protection of the environment, especially matters of National Environmental Significance (NES) and to conserve Australian biodiversity. The EPBC Act includes criteria for assessment of the significance of impacts to NES.
Wildlife Conservation Act, 1950 (WA Govt)	Outlined in detail below.
EPA Guidance Statement No. 1: Protection of Tropical Arid Zone Mangroves along the Pilbara Coastline (EPA 2001)	Addresses the protection of tropical arid zone mangroves, habitats and dependent habitats along the Pilbara coastline from Cape Keraudren at the southern end of the Eighty Mile Beach to Exmouth Gulf.
EPA Guidance Statement No. 8: Environmental Noise (Draft) (EPA 2007)	Outlined in detail below.
Commonwealth Action Plan for Australian Cetaceans (Bannister *et al.* 1996)	Provides recommended conservation priorities, and research and management actions for endangered and vulnerable marine taxa.
Commonwealth Recovery Plan for Marine Turtles in Australia (DEH 2003)	Provides a long term set of objectives and applied actions to reduce the detrimental impacts on Australian populations of marine turtles to promote their recovery in the wild.
Draft Marine Turtle Recovery Plan for Western Australia 2009-2016. Wildlife Management Program No. 45 (DEC 2009)	Provides a 10 year set of objectives and applied actions to reduce the detrimental impacts on Australian populations of four species of marine turtles known to breed on the coast and islands of northern Western Australia. This Plan is aligned with the Commonwealth Recovery Plan (DEH 2003).
EPA Environmental Assessment Guidelines No. 5, Environmental Guidance for Protecting Marine Turtles from Light Impacts (EPA 2010)	Outlined in detail below.
Australian and New Zealand Environment and Conservation Council Code of Practice for Anti-fouling and In-Water Hull Cleaning and Maintenance (ANZECC 1997)	Provides guidance to industry and regulators in applying a consistent approach to the management of these activities particularly the prohibition of Tributyltin.
Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions, April 2005	Sets out a framework to develop, implement and continuously improve the National System for the Prevention and Management of Marine Pest Incursions in Australia.
Australian Quarantine and Inspection Service (AQIS) guidelines for ballast water management (AQIS 2008)	Sets out management guidelines and reporting requirements that are consistent with the International Maritime Organisation (IMO) to minimise the risk of translocation of harmful aquatic species in ships' ballast water.
National Introduced Marine Pest Identification System (NIMPIS) (Hewitt *et al.* 2002)	Is an identification system that aims to prevent new pests arriving, respond when a new pest does arrive, and minimise the spread and impact of pests that are already established in Australia.

EPA Environmental Assessment Guideline No. 5 sets out the policy, legislative and scientific context for protecting marine turtles from light impacts. It aims to improve the scientific understanding of the effects of light on turtles, demonstrates how light impacts can be avoided and mitigated early on during the project design, and it provides potential solutions for impacts that could occur. The key principles for light management can be summarised as:

- keep it off (keep light off the beach and lights off when not needed);
- keep it low (mount lights low down with the lowest intensity for the job);
- keep it shielded (stop all light escaping upwards and outwards); and
- keep it long (use long wavelengths lights).

The Commonwealth Action Plan for Australian Cetaceans identifies a number of threats relating to the project that will require specific management and mitigation measures to be developed such as:

- injury and mortality;
- boat strikes;
- oil spills;
- habitat loss; and
- noise and vibration (acoustic disturbance).

The overall objective of the Commonwealth Recovery Plan for Marine Turtles (DEH 2003) is to reduce detrimental impacts on Australian populations of marine turtles and hence promote their recovery in the wild.

A number of specific objectives have been further defined in the plan which will require specific management strategies to be applied throughout the duration of the project as follows:

- prevention of accidental death (e.g. by boat strikes);
- management of factors that affect successful nesting (e.g. lighting, noise, disturbance to sites);
- identification and protection of critical habitats (e.g. feeding areas, nesting sites, pelagic waters); and
- water quality (e.g. marine debris, oils spills, waste disposal).

10.4.4 Potential Impacts

Potential impacts on marine fauna resulting from aspects associated with the proposed Outer Harbour Development are discussed below and summarised in **Table 10.33**. The key aspects that may impact marine fauna are:

- physical interaction between fauna and construction vessels;
- seabed disturbance leading to a loss of habitat and increased turbidity;
- light spill;
- noise and vibration;
- liquid and waste disposal;
- physical presence of marine structures;
- leaks and spills;
- introduced marine species; and
- presence of increased residential populations.

10.4.4.1 Injury or Mortality from Physical Interactions

Direct mortality may occur from collisions with vessels, dredger entrainment or burial under dredged material during disposal. Permanent injury to marine fauna may also occur from vessel collisions and entrainment in the dredger. The most sensitive marine fauna are considered to be turtles, migratory whales and dugongs. There is no recognised feeding or breeding areas for whales in the immediate vicinity of Port Hedland Harbour. Dolphins are highly mobile and it is likely that these animals will be able to avoid vessels. Dugongs are sighted infrequently in the Port Hedland region, and those observed have generally been single individuals rather than groups. Although seagrass species suitable for dugongs are known to occur in the Port Hedland region, the extent of seagrass areas is not considered adequate to support permanent populations of dugongs.

Turtles, and particularly the inter-nesting females from Cemetery Beach, are the most sensitive to physical interactions from dredging. Preliminary satellite telemetry has shown that the Flatback Turtles nesting at Cemetery Beach use the waters of the existing navigation channel for inter-nesting in addition to the waters immediately offshore and stretching 50 km to the east. The adult Green, Flatback, Hawksbill and Loggerhead turtles from southern Pilbara nesting sites migrate through the area to foraging habitat of the De Grey River. Resident foraging (juvenile and adult Green, Flatback and Hawksbill turtles) and seasonal breeding migrant turtles (principally Flatback) are at greatest risk from vessel collisions, dredge entrainment or burial under dredged material during disposal.

Table 10.31 summarises the predicted vessel movements for each vessel type for the project during construction and operation. Vessel movements will be highest during the construction phase (both in terms of number of movements and the size of the area movements occur in). By far, dredging related movements (the TSHD, survey vessel and support vessels) will result in the greatest amount of vessel movements and have the greatest potential to impact on marine fauna. Smaller craft (pilot vessel, survey vessels etc) will generally have minimal draught and as such would be expected to have little impact on marine fauna close to the sea bed. The larger vessels including the bulk carriers, will have deep draughts and minimal under keel clearance when fully laden. These vessels however, are restricted to designated shipping routes, which minimises the potential impact to marine fauna. TSHDs may also have a limited under keel clearance when fully laden. If required, vessel movements will be planned to avoid key sensitive areas to minimise the potential impact of the TSHD on marine fauna. Sensitive areas (such as habitats that experience a high density of fauna utilisation (i.e. foraging or breeding)) will be determined following completion of pre-development marine megafauna surveys and prior to construction activities that may impact marine fauna.

Figure 10.30 shows the areas of primary vessel movements during the construction and operation phases of the proposed Outer Harbour Development. The figure also shows marine turtle densities based on survey and satellite tracking data. This figure will be updated based on the planned marine mega fauna surveys once completed (refer to **Section 10.4**) and if survey results identify areas of important habitat, these areas will be avoided to minimise the risk of vessel strike.

Table 10.31 – Summary Table of Construction and Operational Vessel Movements

Vessel Type	Speed	Operational Area	Frequency of Movement	Duration
Bulk Carrier (170,000 to 250,000 DWT).	Variable (max 15 kn)	Restricted to designated shipping channel	960 – 1400 arrivals per year plus 960-1400 departures per year	Project Life
Tugs	Variable	In around channel and berths	Frequent	Project Life
Pilot Vessel	Variable speed	In around channel and berths	Frequent	Project Life
Material delivery vessels	Variable (max 15 kn)	Restricted to designated shipping channels	Infrequent	Construction phase
Piling Barges	1–4 kn	Jetty construction area	Infrequent	Construction Phase
TSHD	1–4 kn (dredging) 1–10 kn (transit)	Dredging footprint, spoil grounds and area in between	4-6 movements to and from spoil ground per day for each TSHD	Construction Phase
CSD	4kn (towed), 7-9kn (self propelled)	Dredging footprint	Infrequent	Construction Phase
Support Vessels	Variable speed	Dredging footprint, spoil grounds and area	Frequent	Construction Phase
Survey Vessels	12-15 knots	Area in and around dredging footprint and spoil grounds	Frequent	Construction Phase

10.4.4.2 Loss of Habitat due to Seabed Disturbance

The loss or reduction in quality of habitat may reduce the foraging and breeding areas available for marine fauna. The inability to find habitat easily or in familiar areas may reduce fitness in foraging animals, while lost quality or availability in breeding habitat may reduce reproductive success.

Turtles are considered to be the most sensitive marine fauna. Flatback Turtles use localised and distinct habitats in the Port Hedland area for nesting. In particular, a significant rookery exists at Mundabullangana (approximately 50 km west of the development) and smaller rookeries are present at Cemetery Beach and Pretty Pool (approximately 5 km to the south-east on the other side of the existing harbour channel).

Although juvenile and adult turtles utilise habitat within the project area for foraging and breeding, regionally significant areas occur beyond the project area (Pendoley Environmental 2009). Preliminary satellite telemetry data indicates the most important foraging habitat for Green, Flatback, Hawksbill and Loggerhead Turtles is around offshore islands and near the De Grey River where significant aggregations of Green Turtles have been observed.

Although seagrass species suitable for foraging dugongs are known to occur in the Port Hedland region, the extent of these seagrasses is not considered adequate to support permanent populations.

There is no recognised feeding or breeding areas for whales in the immediate vicinity of Port Hedland Harbour.

10.4.4.3 Behavioural Changes due to Light Spill and Underwater Noise

Altered behavioural responses of marine mammals, turtles and fishes may result from underwater noise generated by piling activities and operation of vessels, and from light spill associated with infrastructure and vessels.

Behavioural responses can range from short-term startle responses to long-term avoidance of areas by animals, including changes to movement and migration routes. Changes in behaviour should not be confused with temporary or long-term physiological injuries (e.g. temporary hearing loss; traumas), which are discussed in **Section 10.4.4.4**. Behaviour responses in mammals, turtles and fishes are much more likely to occur than any type of physical injury during the proposed Outer Harbour Development.

Of the activities with potential to induce behavioural changes, piling and dredging will cease at the completion of the construction phase of the proposed Outer Harbour Development. Non-dredging related vessels will continue to operate throughout the life of the new port facilities.

Underwater Noise

Human generated underwater noise has the potential to modify the behaviour of marine mammals, turtles and fish (Pendoley Environmental 2009). A study into the environmental impacts of underwater noise associated with the Outer Harbour development has been undertaken by Salgado Kent *et al.* (2009). The results of this study are included in **Appendix B9**. It

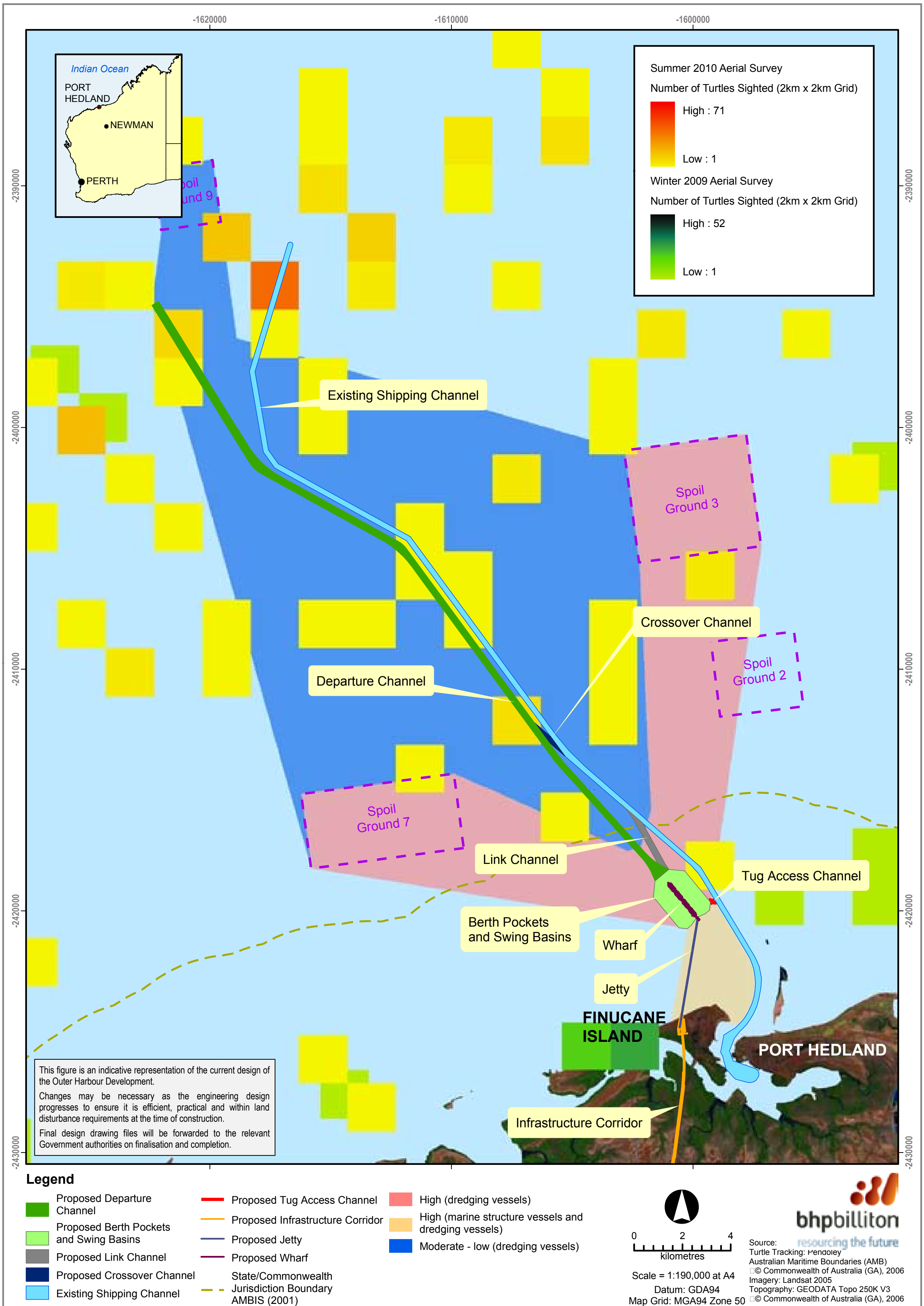

Figure 10.30 Area of Primary Vessel Movements with Respect to Turtle Density Observations

should be noted however that predicting the effect of noise on marine animals is difficult as there is limited information available on the hearing sensitivity of species found in the Port Hedland area (Salgado Kent *et al.* 2009).

The two main sources of underwater noise during the proposed Outer Harbour Development will be pile driving (construction phase only) and vessels. Vessels will include dredgers (trailing suction hopper dredger and cutter suction dredger), as well as bulk carriers using the new wharf.

Altered behaviour attributable to piling will be temporary and restricted to the construction phase of the project only. Pile driving to establish the jetty and wharf structures is expected to involve over 1,000 piles (with 892 driven within the first year). It is intended that at least three jack-up pile driving rigs will be used, with planned simultaneous use through much of the construction phase. Pile driving hammers are large, with a quoted hammer energy output in the range of 30 to 48 t/m (294 to 470 kN/m) (Salgado Kent *et al.* 2009). The deepest sections of the piling activity will occur in waters less than 10 m in depth.

Underwater noise generated by piling is at frequencies that can influence the behaviour of marine mammals (Salgado Kent *et al.* 2009). Whales, dolphins and dugongs are known to move through the proposed Outer Harbour Development area (**Section 6.6.6**), although in low numbers (Prince 2001). The species of primary concern is the Humpback Whale because of its conservation status (listed as vulnerable under Commonwealth legislation) and because a large portion of the population, including calves, follow the Western Australian coastline during a predicable period of the year (Jenner *et al.* 2001). During the Humpback Whale migration season, these animals are normally observed in waters deeper than 20 m (Prince 2001; Jenner *et al.* 2001). This depth contour is approximately 30 to 35 km from the proposed wharf; as such migrating whales would generally occur well beyond the proposed piling location. However, during the southern migration of the Humpback whale (late August–early September), some mother-calf pairs tend to migrate closer to the coast in shallow waters and are likely to be at a risk from noise impacts associated with piling.

Salgado Kent *et al.* (2009) predicted that the underwater noise emissions generated by the three pile drivers over a period of approximately 24 months, could affect the behaviour of marine mammals that come within tens of kilometres of the activity. The zone of actual physical injury (e.g. temporary hearing loss) due to noise is predicted to be 200 m, and death is predicted to only occur within tens of metres (Salgado Kent *et al.* 2009). Behavioural responses may range from startle effects to avoidance of the noise source. In more extreme cases, it may include short to long-term changes to established movement pathways and migration routes (Salgado Kent *et al.* 2009). The severity of the behavioural response will vary depending upon the species, habituation or sensitisation to vessel noise, intensity and distance from source, and the duration of the disturbance.

Marine turtles may potentially move through and forage in the area where piling occurs (Pendoley Environmental 2009a). Two inter-nesting females were known to utilise the existing navigation channel during the 2008/2009 nesting season; however, there are no sandy beaches near the proposed wharf and no major nesting beaches within 6 km of the harbour. Downes Island, 3 km west of the proposed Outer Harbour Development, supports very low nesting activity (Pendoley Environmental 2009). Therefore, the risk of modifying the behaviour of large numbers of hatchlings and nesting females due to underwater noise is low.

Noise levels associated with pile driving will potentially overlap with the noise sensitivity range of turtles (Pendoley Environmental 2009a) which may result in changes to the behaviour of turtles within hearing range of piling activity to change. It is difficult to predict the actual turtle numbers that may be affected as the precise sound levels that will induce behaviour changes are not well understood (Pendoley Environmental 2009a).

There are a limited number of studies of the behavioural responses by marine turtles to noise impacts (Pendoley Environmental 2009a). During experiments, turtles displayed agitated behaviour, abrupt body movements, startle responses, and even prolonged inactivity at the bottom of the tank in response to low frequency signals (Lenhardt *et al.* 1983, 1996). The noise from pile driving during construction of the jetty is considered to pose a medium risk to marine turtles in the area (Pendoley Environmental 2009a). The regular pulses from piling activities may result in avoidance behaviour; however, it should also be noted that marine fauna in the area have been exposed to previous piling activities with the construction works at Anderson (FMG 2008) and Utah (Biota 2007) Points.

Underwater noise produced by vessels is a potential chronic source of impact which may result in altered behaviour. Vessel traffic is expected to increase to about 960 ships per annum for the proposed Outer Harbour Development, with an additional 960 ships associated with BHP Billiton Iron Ore Inner Harbour operations, many ships of smaller sizes, and shipping associated with other companies (Salgado Kent *et al.* 2009).

Salgado Kent *et al.* (2009) suggested that behavioural disturbance is likely for most species that occur within close proximity to continuous noise sources, such as a moving vessel. Continuous noise sources will include dredging vessels as well as shipping movements along the new channel (parallel to the existing channel). Humpback whales and dugongs are likely to exhibit negative behavioural responses to fast moving vessels by rapidly changing direction or showing a startle response if a vessel moves too close.

With the exception of recently born calves, most of these animals will have become habituated to vessel noise and movement that already exist in the Port Hedland area. Not all responses are predicted to be negative. Some dolphin species, such as the Bottlenose dolphin, may move towards a moving vessel in order to swim in the bow wave.

Although direct impact by fast moving small vessels is a potential source of injury (Hazel *et al.* 2007), there are a limited number of studies showing behavioural responses by marine turtles to noise impacts associated with vessels. For dredging and general boat traffic marine turtles are predicted to exhibit disturbance responses at around 120 to 180 dB re 1 µPa MSP (O'Hara & Wilcox 1990; Samuel *et al.* 2005).

Most marine fishes do not have any auditory specialisations or more sensitive hearing abilities. They only hear up to approximately 1,500 Hz (as opposed to 20,000 Hz for humans) and have relatively high hearing thresholds at these low frequencies (sounds must be reasonably loud before they become audible to these fish). It is known however, that impulsive signals such as those produced from pile drivers, can cause behavioural changes to fishes (Nedwell *et al.* 2004). Several studies have attempted to quantify non-mortality injuries that resulted from pile driving, but the degrees of damage in these studies are not readily quantifiable or comparable between studies (Salgado Kent *et al.* 2009). Other unpublished reports have attempted to observe the behaviour of fish during pile driving activities. For example, Feist *et al.* (1992) found that there were more fish schools in an area when there was no pile driving activity than when there was pile driving activity. None of these studies, however, reported any other notable effects on fish behaviour.

Light Spill

Artificial lighting at night has the potential to modify the behaviour of marine turtles by deterring females from nesting beaches, and disorienting hatchlings on the beach and at sea.

Light from the proposed Outer Harbour Development may affect nesting females on Downes Island (Pendoley Environmental 2009). According to Pendoley Environmental (2009), the risk to nesting females is considered to be low, given the level of lighting from existing urban and industrial development and the low numbers of turtles nesting at Downes Island. The next closest nesting beach is Cemetery Beach (6 km to the east).

To assess the effects of light spill from the proposed Outer Harbour Development on nesting beaches, BHP Billiton Iron Ore commissioned a study to predict the intensity and spatial extent of light spill from the proposed facilities (Bassett 2009). Potential sources of light include land based facilities, jetty, wharf, shiploader and conveyor lights as well as moored and operating dredging and export vessels. Light spill was considered in terms of cumulative port development light spill (proposed Outer Harbour Development and existing port development light spill) and cumulative ambient light spill (proposed Outer Harbour Development light spill and existing ambient light levels at the sites).

The main conclusions of the Bassett (2009) study were:

- light spill from the proposed Outer Harbour Development is unlikely to be visible at the turtle nesting beaches near Cooke Point and Pretty Pool (east of Cemetery Beach) due to the presence of high sand dunes at these sites and the large distance (greater than 7 km) of these sites from the proposed development;
- during construction, high pressure sodium vapour and metal halide and mercury vapour lighting on ships and dredge vessels will be visible at Cemetery Beach. The high pressure sodium vapour lighting on the proposed jetty, shiploader area and transfer station will also be visible from Cemetery Beach;
- illuminance levels and cumulative ambient lighting levels for the proposed Outer Harbour Development are predicted to be less than those associated with moonlight. Modelling results for the proposed Outer Harbour Development do not indicate a noticeable increase in existing port development lighting or ambient lighting at turtle nesting beaches;
- under some atmospheric conditions, the lighting of the proposed Outer Harbour Development will marginally increase sky glow seen from residential sites (depending on observer position) and Cemetery Beach; and
- the overall effect is not expected to be significantly brighter than existing sky glow.

Following initial light surveys by Bassett (2009) and in accordance with directives outlined by the EPA (2010), a comprehensive and biologically relevant assessment of light effects was conducted to provide interpretation regarding perception of artificial light sources by marine turtles in the vicinity of Cemetery Beach. This assessment, once amalgamated with data that describe actual hatchling orientation in the period immediately following emergence from the clutch (Pendoley Environmental 2011c), will identify the relationship between light sources and hatchling orientation on Cemetery Beach. Values determined via this study will describe baseline for future assessments. Future hatchling behaviour will be modelled against these findings to allow identification of any dis – or misoriented hatchlings resulting from light generation by the Outer Harbour Development.

In summary, it is unlikely that light spill from the proposed Outer Harbour Development will have a significant or detectable effect on nesting female marine turtles (Bassett 2009; Pendoley Environmental 2009). A small portion of hatchlings may be exposed to the lights from the proposed wharf, jetty and vessels from the proposed Outer Harbour Development and become entrapped in the light spill, increasing predation risk and reducing hatchling survival rate (Pendoley Environmental 2009). To reduce this risk, light spill onto the water will be minimised using luminaries with asymmetric light distribution.

10.4.4.4 Changes to Physiology due to Underwater Noise and Increased Turbidity

Underwater Noise

According to Salgado Kent *et al.* (2009) (**Appendix B9**), physiological impacts to marine animals from noise can be categorised into:

- organ damage – physiological damage to fauna which may lead to death;
- permanent threshold shift (PTS) – a permanent shift in hearing sensitivity; and
- temporary threshold shift (TTS) – a temporary effect upon hearing which is recoverable.

Construction work is proposed 24 hours per day, seven days per week (with favourable conditions); and pile driving will take place 12 hours per day (between the hours of 7 am and 7 pm), for seven days per week. The risk of physiological impacts is predicted to be low for mobile fast moving animals because of their capacity to rapidly avoid sources well before being exposed to sound levels that could induce injury. To reduce the risk to marine mammals from the sudden commencement of a sound source it is proposed to use soft-start piling.

Marine fauna will be subject to at least two, and probably three years of acoustic emissions. It is important to note that these years are not necessarily consecutive. It is highly likely that this exposure will coincide with critical windows such as turtle breeding and hatchling season and the Humpback Whale migration period. These critical windows will be taken into consideration during the planning of the works, although it is unlikely that they can be entirely avoided.

There is limited data on noise levels that cause physiological impacts to marine mammals (Salgado Kent *et al.* 2009). Richardson *et al.* (1995) extrapolated sound levels required to produce PTS (e.g. permanent shift in hearing sensitivity) in marine mammals from information on human threshold levels, which was based on levels 80 dB above hearing threshold causing PTS in humans (exposure of eight hours a day over approximately 10 years). According to Salgado Kent *et al.* (2009) impulsive hammering sounds may present a greater risk than continual shipping sounds because of higher peak levels. However, there is limited information on levels of impulsive sounds which cause TTS or PTS in marine mammals making prediction difficult.

A summary of the estimated impacts for all groups of animals based on Salgado Kent *et al.* (2009) is presented in **Table 10.32**.

Salgado Kent *et al.* (2009) reported that dugongs are highly sensitive to sound, and often show changes in behaviour even in response to low sound levels (within their hearing range). In order to predict the risk to marine mammals during piling, Salgado Kent *et al.* (2009) provide the following radii from which death or injury may be expected at an active piling site:

- injury/death: within several to tens of metres from the source;
- PTS: within tens of metres from the source; and
- TTS: within 200 m from the source.

The authors estimated that physiological injury to marine mammals is unlikely beyond 200 m of an active piling source.

Very little is known about the hearing ability or physiological responses of marine turtles to underwater noise. However, the frequencies from dredging and pile driving are believed to overlap the sensitivity range of turtles recorded in previous studies (Pendoley Environmental 2009). TTS in hearing occurred in Loggerhead turtles exposed to many pulses from a single airgun less than 65 m away (Moein *et al.* 1994). Using data available on TTS in response to impulse noise for tortoises

(Bowles *et al.* 1997) an estimate of repeated pulses (three second duration) above 185 to 199 dB re 1 μPa at the most sensitive hearing frequencies may result in TTS in Leatherback turtles (Eckert *et al.* no date).

Turtles are unlikely to experience TTS or injury from shipping or dredging noise; however there is a possibility of TTS or an increase in boat strikes if they become habituated to the noise and remain within the vicinity for some period (Pendoley Environmental 2009).

According to Salgado Kent *et al.* (2009), noise levels from pile driving and dredging overlap the frequencies of greatest known sensitivity of many fish species (approximately 60 to 4 kHz). However, it is noted that the extent of potential noise impacts on fish is not comprehensively understood. Nonetheless, it is known that intense impulsive signals such as those produced from pile drivers, can cause fish kills (Nedwell *et al.* 2004). No evidence of fish kills were observed in association with pile driving exercises undertaken in the Inner Harbour as part of the recent construction activities. A number of species found inside the harbour that would have been subject to noise from these works are also found offshore of Port Hedland.

High-intensity sounds may temporarily or permanently damage fish audition. Damage to hearing by intense sound depends on the auditory threshold of the receiving species and will consequently vary from species to species (Popper & Fay 1973, 1993). The highly variable auditory sensitivity of fishes means that it is impossible to generalise the impact of impulse signals from one species to another. While no studies dedicated to measuring mortality in relation to noise exposure levels have been conducted, there are some observations from pile driving sources.

Studies on explosives are relevant to pile driving as the characteristics of the signals are similar. Nedwell *et al.* (2004) observed that fish kills occurred at a distance of 400 m from an explosive source, but did not occur where the estimated received peak level was only 134 dB re 1μPa. Most fish possess a swim bladder which is a gas-filled organ used for both communication and buoyancy. A rapidly changing acoustic field can cause the swim bladder to contract and expand suddenly, resulting in physical injury or death.

Studies by Hastings and Popper (2005), and McCauley *et al.* (2003) have examined other 'hearing generalists'. The most relevant research was by McCauley *et al.* (2003) which showed that Pink Snapper, approximately 230 mm in length, suffered permanent hearing loss when exposed to a sound pressure level of approximately 180 dB re 1μPa.

Increased Turbidity

Dredging and spoil disposal activities have the potential to increase suspended solids which can lead to gill injuries and mortality in fish. The extent of the damage depends not only on the suspended sediment concentration, but also on the duration of the exposure and the size and shape of the sediment particles (SKM 2009n).

Freshwater fish that suffer mortality from exposure to TSS concentrations of <10,000 mg/L have been classified as sensitive to suspended sediments and those suffering mortality at TSS concentrations less than 1,000 mg/L as "highly sensitive". In a physical capacity, the impacts arising from TSS concentrations and the effects on freshwater species would be directly relatable to marine species.

Dredging and disposal operations are highly unlikely to generate total suspended solid concentrations above 1,000 mg/L or even 500 mg/L, except in the immediate proximity of the dredge head or directly below disposal operations. Maximum TSS concentrations predicted for this project are approximately 400 mg/L in close proximity to dredging activities. In the broader area, maximum predicted TSS concentrations are 150 mg/L (refer **Section 10.2.4.1**). Threshold concentrations for TSS levels during dredging are generally set well below 500 mg/L. Example water quality thresholds during dredging for a study in North Western Australia were 10 to 35 mg/L (MScience 2007).

Fish are expected to move away from levels of suspended sediment that will induce mortality or adverse sub-lethal effects, elevated levels of suspended sediments due to dredging and disposal activities are unlikely to cause adverse physiological effects in fishes.

10.4.4.5 Liquid and Waste Disposal

Ingestion of Solid Wastes

In the event that solid and liquid wastes are disposed of into the marine environment from marine vessels or infrastructure, marine fauna (e.g. turtles, fish, birds) may be attracted to food scraps/ sewage and may ingest solid wastes that are potentially harmful (e.g. polystyrene containers, plastic bags).

Toxic Effects of Discharges

Leaks or spills of diesel, oils or chemicals into the intertidal or marine environment may prove toxic to marine fauna through ingestion or dermal contact. The intertidal reef platform on the western side of Finucane Island provides a foraging area for birds and in the event of leaks or spills this food source may be reduced (through lethal effects on flora and fauna) or contaminated. Leaked or spilt liquids in the

Table 10.32 – Summary of Estimated Impacts on Marine Fauna from Underwater Noise

Species	Death		PTS		TTS		Behavioural response	
	Received Level	Distance	Received Level	Distance	Received Level	Distance	Received Level	Distance
Fish – Hearing Specialists	Unknown expected to be > 200 dB (RMS)	Within several m	Unknown, expected to be > 190 dB (RMS)	Within tens of m	Unknown, expected to be > 180 dB (RMS)	Within 200 m	Unknown, expected to be > 120-150 dB (RMS)	kms to tens of km
Fish – hearing generalists	Unknown, expected to be > 200 dB (RMS)	Within several m	Unknown, expected to be > 190 dB (RMS)	Within tens of m	Unknown, expected to be > 190 dB (RMS)	Within 100 m	Unknown, expected to be > 150 dB (RMS)	several kms
Dugongs	Unknown, expected to be > 200 dB (RMS)	Within several m	Unknown, expected to be > 178-198 dB (SEL)	Within tens of m	Unknown, expected to be > 183 dB (SEL)	Within 200 m	Unknown, expected to be > 120-150 dB (SEL)	~2 kms to tens of km
Dolphins	Unknown, expected to be > 200 dB (RMS)	Within several m	Unknown, expected to be > 178-198 dB (SEL)	Within tens of m	expected to be > 183 dB (SEL)	Within 200 m	Unknown, expected to be > 120-180 dB (SEL)	~2 kms to tens of km
Whales	Unknown, expected to be > 200 dB (RMS)	Within several m	Unknown, expected to be > 178-198 dB (SEL)	Within tens of m	expected to be > 183 dB (SEL)	Within 200 m	Unknown, expected to be > 120-150 dB (SEL)	~2 kms to tens of km

Source: Salgado Kent et al. (2009)

intertidal environment surrounding Finucane Island will be dispersed by regular tidal flushing, with the exception of hydrocarbons which may persist in the environment. The external contact of marine fauna with leaked or spilt hydrocarbons into the marine environment may result in chronic or acute toxic action, leading to impaired physiological function or death. Physical contact with leaked or spilt fluids may in some instances lead to accidental or unavoidable ingestion, particularly for permanently immersed aquatic organisms (e.g. invertebrates).

10.4.4.6 Physical Presence of Marine Structures

Physical structures to be constructed as part of the marine infrastructure include the access jetty, transfer station deck, wharf structure, navigation aids, and berthing dolphins. The jetty will be located in very shallow water (less than 3 m depth) where the presence of large marine mammals (e.g. humpback whales) is unlikely. These structures will be steel piled and are not expected to block or impede the movement of any marine fauna.

A sediment transport study has been undertaken by GEMS to assess the potential impact of this infrastructure of the sediment transport regime in the Port Hedland area. This study found that the most likely effects are a slight reduction in waves due to sheltering with minor refraction effects. The proposed wharf, which is less permeable than the jetty, provides the most significant component of sheltering, however, its ratio of length to distance offshore is small, limiting its effectiveness for providing a zone of sediment capture. The study found that sediment transport rates in the area are controlled by low sediment supply rather than variation in transport potential, and combined with the rocky nature of the shore, this limits any significant coastal response, whether erosion or accretion, as a result of the proposed marine infrastructure (GEMS 2009).

The GEMS study also analysed spoil ground stability through a combination of modelling, interpretation of existing seabed sediments and the evolution of the spoil grounds previously used by the PHPA. The study found that none of the proposed spoil disposal sites are in areas likely to cause significant onshore sediment movement (GEMS 2009).

Due to the design and location of the proposed marine structures, their presence is not expected to impact on marine fauna.

10.4.4.7 Introduction/Establishment of Invasive Marine Species

Invasive marine species may be introduced to an environment through biofouling on vessel hulls, internal niches (e.g. sea chests, strainers, seawater pipe work, anchor cable lockers and bilge spaces), biofouling on equipment (e.g. dredging equipment, cutters, ladders, and deck mounted tender vessels) and discharge of ballast water. Following introduction to an environment, non-indigenous species may establish and out-compete local species resulting in a loss of biodiversity and ultimately ecological function of an area. The risk of establishment occurring is elevated with the generation of artificial substrates through construction of infrastructure. Introduced species may also result in the presence of new diseases (viruses and bacteria) and other microorganisms (e.g. dinoflagellates) for the local population, particularly for fish assemblages, pearl oysters and other cultured species. Several invasive species have been recorded in Port Hedland Inner Harbour.

Through the establishment of preventative measures including inspections prior to entrance of vessels into the project area and implementation of ballast controls as per AQIS (2008), the potential of invasive marine species being introduced to the Port Hedland is considered very unlikely.

10.4.5 Management Measures

Marine fauna may be impacted by the proposed Outer Harbour Development through physical interactions with construction and operation vessels leading to injury or mortality; loss of habitat leading to changed/lost foraging or breeding grounds; changes in behaviour and physiology due to noise and light; contamination from chemicals and wastes; and added competition for resources through introduction of invasive marine pests. These potential impacts will be managed via proposed avoidance, mitigation, monitoring and contingency measures. The management measures applicable to impacts to marine fauna arising from the construction and operation of the proposed Outer Harbour Development are summarised in **Table 10.33**.

Impacts on marine fauna will be managed primarily through measures and controls as detailed in the Marine Turtle Management Plan (MTMP) (**Appendix A1**), Marine Mammal Management Plan (MMMP) (**Appendix A4**), and the Invasive Marine Species Management Plan (IMSMP) (**Appendix A5**). The management strategies proposed in these management plans will be consistent with the objectives of relevant legislation, policies, and action plans.

Key management measures proposed within these plans include:

- extensive management measures for the protection of marine fauna during construction and operation activities of the proposed Outer Harbour Development including trained fauna observers present on construction vessels; soft-start to activities that generate noise; reduced vessel speeds; and
- implementation of a number of marine quarantine measures, including inspections (IMS inspections) and ballast controls as per ANZECC (1997) and AQIS (2008), has been proposed to reduce the likelihood of the introduction of non-indigenous marine species.

To further inform the implementation of these management plans, pre-development aerial marine mega fauna surveys of the project area will be undertaken to:

- determine the seasonal distribution and relative abundance and densities of marine mammals within the marine study area during a 12 month seasonal cycle; and
- analyse the relative importance of the modelled sub-tidal habitats within the project area for conservation significant marine mammals.

A systematic and comprehensive aerial transect sampling method will be utilised to estimate the abundance and distribution of marine mammals in the marine study area. Transects will be designed to be consistent and comparable with other marine mega-fauna surveys undertaken in the region. Transects will include the main Humpback Whale migratory pathway.

Surveys will be undertaken over a 12 month period. Analysis of the survey data will include:

- temporal and spatial analysis to determine relative densities of marine mammal species in the marine study area over the 12 month period;
- determination of the distribution of Humpback Whales during the northern and southern migration periods;

- analysis of the spatial patterns of milling/resting whales and cow/calf pods;
- analysis of the abundance and distribution of other marine mammals; and
- correlation of marine mammal distribution and modelled sub-tidal habitat, to determine if sub-tidal habitat is present to support conservation significant species.

The surveys and analysis will be completed prior to the commencement of marine construction activities that may affect marine mega-fauna and submitted to the DEC. The MMMP will be updated based on the results of the surveys prior to the commencement of marine construction activities that may affect marine mammals.

10.4.6 Significance of Residual Impact

No significant impact to marine fauna at the population or ecosystem level, including matters of National Environmental Significance is expected to occur as a result of the proposed Outer Harbour Development.

Extensive specialist studies into a number of these aspects have been undertaken, particularly for marine fauna listed under the EPBC Act. The studies established that although individual organisms may be susceptible to harm, the populations at large will not be unduly affected by the activities proposed under the proposed Outer Harbour Development. Regionally significant foraging and breeding habitats will not be significantly affected by the proposed Outer Harbour Development. The likely consequences on marine fauna will be restricted to local and temporary changes in behaviour and will not result in a reduction in local population viability.

The EPBC Act defines criteria for a significant impact for each category of listed marine fauna (i.e. Critically Endangered or Endangered, Vulnerable, Migratory). Based on the criteria provided, and the studies undertaken, it is considered unlikely that there will be a significant impact to marine fauna listed under the EPBC Act. The lack of predicted impacts at the population or ecosystem levels is largely attributable to the nature of the existing marine environment and the proposed management measures that will be implemented throughout the project.

Marine Reptiles

- Many of the significant marine fauna present (e.g. turtles) are transitory or visitors to the project area, with more significant habitats supporting feeding and breeding located either to the north or south of the project area.
- Noise associated with vessel activity is unlikely to result in turtle population level effects given that vessel activity is already common in the area, it is likely that turtles that frequent the project area are habituated to noise from vessels.
- The proposed piling activities will not occur adjacent to any major turtle rookery and the soft-start piling and the use of trained fauna observers will limit the risk of behavioural changes in turtles due to the effect of noise from pile driving activities.

Marine Mammals

- Because the proposed channel will not cross migratory, feeding or calving habitat for any species of marine mammals, noise associated with vessel activity during the proposed Outer Harbour Development is unlikely to result in population effects on marine mammals. Management measures in the form of observers will reduce the risk of dredgers moving close to marine mammals and any behavioural changes that may result will not lead to mortality of individuals. Therefore, impacts are considered likely to be negligible.
- Although underwater noise and light pollution are likely to influence the behaviour of individual animals over the construction period, management measures including soft-start piling and trained fauna observers will result in negligible behavioural changes. Furthermore, the piling will be temporary, and will only occur in waters 10 m or less, which is 30 to 35 km from the 20 m depth contour where most Humpback whales are observed migrating.

Fish

- Given that no unique habitat or species of restricted distribution are known to occur at Port Hedland, the impact from dredging and local loss of habitat is unlikely to cause any impact on fish at the population level and therefore will be negligible.
- Pile driving will undoubtedly have an influence on fishes moving through the area, but soft-start piling activities will minimise behavioural changes. The effects of noise on fishes associated with piling and vessels are unlikely to result in population level effects because the habitat over which vessels move and in which piling will occur is primarily unvegetated sand with low species diversity and densities. The proposed Outer Harbour Development area does not support endemic species with highly restricted distributions.

- Three species of Sawfish are listed as 'Vulnerable' under the EPBC Act; the Green Sawfish, Dwarf Sawfish and Freshwater Sawfish. As noted in **Section 6**, the Freshwater Sawfish and the Dwarf Sawfish are unlikely to occur in the project area and therefore any potential impact from the Outer Harbour Development on these species is considered negligible. The Green Sawfish is the most commonly distributed species in Western Australian waters, occurring in areas with a muddy substrate and is frequently found in shallow water (Stirrat *et al.* 2006). Whilst Morgan *et al.* (2010) identified limited records of catches near Port Hedland, it is likely that they occur in the Port Hedland area (D. Morgan, pers. comm). Pupping of juvenile Green Sawfish occurs in tidal creeks and therefore these creeks could be considered a critical habitat in their life-cycle. It is not known, however, which tidal creeks in the Pilbara region are important pupping areas (i.e. nursery areas) and whether these creeks occur in the vicinity of Port Hedland.
- The Port Hedland area is not a known aggregation or feeding site for the Whale Shark (ChevronTexaco 2005). This species is likely to be an infrequent visitor to the project area and is most likely to remain in deep waters along the continental shelf (DEWHA 2008). As such there is not expected to be any impact to Whale Sharks as a result of the proposed Outer harbour Development. It should be noted however, that in the event Whale Sharks are sighted in the area during construction activities, the same management response that applies to Humpback Whales will be undertaken (refer to the MMMP (**Appendix A4**)).

10.4.7 Predicted Environmental Outcomes

The predicted environmental outcomes for marine fauna as a result of the proposed Outer Harbour Development are:

State

- Although individual organisms may be impacted during the proposed Outer Harbour Development, impacts will not occur at the population or ecosystem levels.
- The EPA's objectives for the maintenance of abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels, and improvement in knowledge, will be achieved under the proposed construction and operational measures.
- Operational management measures in combination with the zone of moderate ecological protection proposed around the marine facilities will ensure that the EPA's objectives of maintaining marine ecosystem integrity and use of the environment for recreation and aquaculture are met (refer to **Section 6.7.2**).

Commonwealth

- It is unlikely that there will be a significant impact to any marine fauna listed as "Endangered, Vulnerable, Migratory" under the EPBC Act.

Table 10.33 – Summary of Potential Impacts and Management Actions Associated with Marine Fauna

Environmental Aspect	Source	Impacts	Management
Physical interaction	Dredging and dredge spoil disposal – all dredging operations	Injury or mortality to marine fauna (Marine Mammals, Marine Reptiles) as a result of collisions or entrainment in dredger	Further investigations into the presence of Green Sawfish in the project footprint will be undertaken. The results of these investigations will be included in the Final PER/EIS. *Avoidance/Mitigation/Management Measures:* Note, within the following management measures, marine fauna refers to marine turtles, marine mammals and whale sharks (but does not include dolphins). Where a management measure applies only to marine turtles or marine mammals (except dolphins) this is stated. **General** ▸ Prior to commencement of construction, designated crew (one per vessel) will be trained as Marine Fauna Observers, and trained to observe for marine turtles and marine mammals, record sightings and the actions to be taken in event of sightings, injury or mortality. ▸ Site inductions for all vessel crew and awareness programs covering procedures to be undertaken to minimise disturbance to marine fauna. ▸ Operators of specified vessels will be required to maintain a watch for marine turtles and marine mammals, and if they are spotted, vessels will avoid impacting the fauna (within safe operational constraints of the vessel). ▸ If marine mammals or marine turtles are sighted in the area, relevant project vessels operating in the area will be notified. ▸ The maximum allowed speed for construction vessels will be in accordance with Port Hedland Port Authority Regulations. ▸ A log detailing marine turtle and marine mammal (except dolphin) sightings will be maintained on all vessels. ▸ Any incidents that relate to mammal injury/mortality will be documented and reported to BHP Billiton Iron Ore. BHP Billiton Iron Ore report all incidents of injury or mortality to the DEC and DSEWPaC within 48 hours.
Physical interaction	Dredging – CSD Specific	Injury or mortality to marine fauna (Marine Mammals, Marine Reptiles) as a result of entrainment in dredger	**CSD Operations** ▸ Within the operating constraints of the CSD, the dredge pumps will only be turned on when the cutter head is close to the sea bed. ▸ Within the operating constraints of the CSD, the dredge pumps will be turned off as soon as possible after the cutter head clears the sea bed (generally after the discharge pipe is clear).

Table 10.33 – Summary of Potential Impacts and Management Actions Associated with Marine Fauna (continued)

Environmental Aspect	Source	Impacts	Management
Physical interaction	Dredging and dredge spoil disposal – TSHD Specific	Injury or mortality to marine fauna (Marine Mammals, Marine Reptiles) as a result of collision or entrainment in dredger	**TSHD Dredging Operations** ▸ Upon arrival at the dredging location (each cycle) and prior to the commencement of dredging, the area within 300m of the dredge (exclusion zone) will be visually inspected (during daylight hours). If any marine fauna are sighted within the exclusion zone, dredging will not commence until the marine fauna has moved out of the exclusion zone or has not been sighted for 10 minute (note : the dredge may move location to ensure the marine fauna is out of the exclusion zone). ▸ Within the operating constraints of the THSD, the dredge pumps will only be turned on when the drag head is close to the seabed. ▸ Within the operating constraints of the TSHD, the dredge pumps will be turned off as soon as possible after the drag head clears the seabed (generally after the dredge pipes are clear of dredged slurry). ▸ The vessels MFO will maintain a watch for the marine fauna (during daylight hours) during the dredging operations. In the event that a marine fauna enters the exclusion zone during the dredging works, dredging operations will cease until the marine mammal is outside of the exclusion zone or has not been seen for 10 minutes. ▸ During transit avoidance action will be taken where necessary to attempt to maintain a distance of 1000 m or more between vessel and whales. ▸ During transit, if a marine mammal is sighted within 300 m, a maximum vessel speed of 6 knots will be applied. ▸ Turtle exclusion devices (tickler chains) will be used. The type of exclusion device utilised will be similar to that used on project throughout Western Australia. **TSHD Spoil Disposal Operations** ▸ Upon arrival at the spoil ground (each cycle) and prior to the commencement of disposal operations the area within 300 m of the dredge (exclusion zone) will be visually inspected. If any marine fauna are sighted within the exclusion zone, disposal will not commence until the marine fauna has moved out of the exclusion zone or has not been sighted for 10 minutes (note : the dredge may move location to ensure the marine mammal is out of the exclusion zone).
Seabed disturbance	Dredging and dredge spoil activities	Reduction in productivity due to reduced developmental and foraging habitat	*Avoidance/Mitigation/Management Measures:* ▸ Placement of spoil disposal grounds in areas with low representation of significant BPPH.
		Physiological damage to fish gills from abrasive sediments leading to the migration of fish away from the area	

Table 10.33 – Summary of Potential Impacts and Management Actions Associated with Marine Fauna (continued)

Environmental Aspect	Source	Impacts	Management
Light spill	Construction and operational vessels	Marine fauna behavioural changes	*Avoidance/Mitigation/Management Measures:* ▸ Minimise light intensity to as low as reasonably practicable in nearshore areas. ▸ Avoid use of white lights (e.g. mercury vapour, metal halide, halogen and fluorescent light) in proximity to turtle beaches. Use high pressure sodium lights where possible. ▸ Reduce lighting spill through shielding, directional alignment, window covering and other techniques. ▸ Reduce horizon glow through the use of downward facing luminaries, attention to reflecting surfaces and minimisation of external visibility of indoor lighting. ▸ Lighting on moored vessels at night will be kept to a minimum for safe operations. ▸ Periodic monitoring of the waters by trained vessel crew around dredge vessels during construction and around the jetty during operations for the presence of hatchlings.
	Permanent marine infrastructure (jetty and wharf)	Adverse affects on the navigation of turtles (including hatchlings) and other marine fauna	
	Permanent terrestrial infrastructure and facilities	Light may deter nesting females from emerging on nesting beaches leading to reduced nesting success Light overspill or glow may have adverse affects on navigation of turtles (including hatchlings) and other marine fauna	
Marine noise and vibration	Construction of marine facilities	Physiological damage from construction activities (e.g. piling)	BHP Billiton Iron Ore will undertake further marine noise and vibration modelling once the marine contractor is selected. The results of this further modelling will be included in the Final PER/EIS. *Avoidance/Mitigation/Management Measures:* ▸ Vessel and construction equipment will be well maintained to minimise noise emissions. ▸ Vessel crew will undertake site inductions and awareness programs covering procedures to be undertaken to minimise disturbance to marine fauna. ▸ Soft start for piling to be undertaken to allow marine fauna close to the source to move away. ▸ The marine fauna observers to record fauna in the vicinity of operations. ▸ A marine fauna watch system will be established with a direct line of communication between the fauna observer and the pile drive supervisor. ▸ Trained fauna observers will monitor and report observations of marine turtles within a designated monitoring zone (2500m radius of piling barge) around the pile driving operations. In the event that marine fauna is sighted within a designated exclusion zone (2000m radius for marine mammals, 500m radius for marine turtles), piling activities will cease until the individual marine mammal moves outside of the exclusion zone or is not sighted for 20 minutes. Note that this procedure does not apply to dolphins. *Monitoring:* ▸ The marine fauna observers will complete daily records of all sightings and report incidents to BHP Billiton Iron Ore who will determine appropriate actions.
		Behavioural responses causing deviation of whale migratory routes	
		Change of foraging/ habitat use (dolphins and dugongs)	

Table 10.33 – Summary of Potential Impacts and Management Actions Associated with Marine Fauna (continued)

Environmental Aspect	Source	Impacts	Management
Liquid and solid waste disposal	Domestic waste and treated sewage	Ingestion of solid wastes from vessel discharges	*Avoidance/Mitigation/Management Measures:* ▸ Waste hierarchy program will be developed. ▸ Wastes will be stored in appropriate containers and facilities with clear signage. ▸ Waste will not be released into the marine environment. ▸ Vessels will be maintained in a clean and tidy manner. ▸ Collection of domestic rubbish which is recycled and/or disposed at the municipal landfill. ▸ Storage/segregation of recyclable materials in a designated area until their removal from site. ▸ Reuse or recycling of containers where possible. ▸ In event of spillages of waste to the environment the vessel master will immediately notify BHP Billiton Iron Ore.
Leaks and spills	Storage and transport of chemicals, fuels or other hazardous materials Failure of equipment or pipelines	Toxicity from diesel/oil spills from vessels affecting marine biota	*Avoidance/Mitigation/Management Measures:* ▸ Appropriate storage and handling of chemicals, fuels and other hazardous material. ▸ Spill contingency plans to manage refuelling, storage and spill management. ▸ Spill response kits will be located in close proximity to storage areas for prompt response in an event.
Physical presence	Dredging and construction vessels	Introduction and subsequent establishment of invasive marine species Generation of artificial substrates from project infrastructure	*Avoidance/Mitigation/Management Measures:* ▸ A risk assessment will be undertaken for all vessels and/or immersible equipment prior to arrival on site to determine the likelihood of the vessel and/or immersible equipment being infected by IMS. All dredging vessels to be mobilised from outside Port Hedland will undergo IMS inspection prior to commencement of activities. ▸ The application of the risk assessment procedure will be undertaken in consultation with the DoF. Completed Vessel / Equipment Risk Assessment Scoring Sheets (VRASS or ERASS) will be provided to the DoF, and consultation will occur with respect to the determined IMS risk status and any required management measures prior to the vessel / equipments mobilisation. ▸ If suspected introduction of marine species are identified during pre-mobilisation inspections or vessel risk assessment, vessels will be subject to cleaning and reinspection prior to remobilisation. ▸ Implementation of ballast controls as per AQIS (2008).

10.5 Key Factor – Geomorphology and Coastal Processes

The following sections present the assessment of impacts on the geomorphology and coastal processes associated with the proposed Outer Harbour Development, incorporating design modifications, mitigation and management measures applied to manage predicted impacts. Potential changes to coastal processes from the presence of the Project are described. Nearshore infrastructure placement (abutments, creek crossings) and offshore modification to the seafloor (turning basins and shipping channels).

10.5.1 Management Objectives

The management objectives that will be applied for the project for the environmental factor, coastal processes are to maintain:

- the integrity and stability of the coast, seafloor, the intertidal environment and the tidal creek systems; and
- the integrity, ecological functions and environmental values of the seabed and coast.

10.5.2 Description of Factor

Geomorphology is the scientific study of landforms and the processes that shape them. The term ‘coastal processes’, refers to the interaction of coastal landforms, coastal hydrodynamics and the distribution of sediments. Changes to any one of these components are likely to cause corresponding changes to the remaining two, often with resultant change to coastal habitats. Baseline characteristics of coastal geomorphology and coastal processes and the impacts associated with this project were assessed through two main studies by Global Environmental Modelling Systems (GEMS) and Asia-Pacific Applied Science Associates (APASA).

Swell waves and locally generated waves produce coastal landforms such as beaches and cause sea-front erosion. Prevailing onshore winds (west to north-westerly) develop coastal dunes. Episodic cyclones and storm surge can cause flash flooding of inshore creeks, and erosion and dispersion of coastal sediment, in particular, creek erosion of mud deposits and fluvial and shoreline accretion.

Coastal landforms in the project area include a sandy beach and low limestone cliff near the location of the proposed jetty on the north side of Finucane Island with lines of sand dunes above the beach and a low rocky limestone platform extending seaward from the intertidal zone. To the south of Finucane Island the landform is one of silty tidal channels fringed with mangroves, mud flats, salt flats and sandy plains. Dredging and construction activities will alter the existing configuration of the Port Hedland nearshore environment, and alter tidal flows in West Creek with the construction of a causeway.

10.5.3 Assessment Guidance

While no formal assessment framework for coastal processes exists at a State and Commonwealth level, the Western Australian Department of Planning has a document that guides coastal planning activities and addresses coastal development. This policy does not have a firm legislative basis however provides coastal management objectives that should guide coastal development including areas in and around port developments. This policy is listed in **Table 10.34**.

It is also likely that potential changes to coastal processes including environmental flows of creek systems may be considered in relation to coastal habitats under the State EP Act and associated Environmental Assessment Guidance documents EAG No. 3 (EPA, 2009) and GS 1 (EPA 2001) (**Section 10.3.3**). The form, location and quality of coastal infrastructure that influence erosion such jetties are controlled under the *State Jetties Act 1926*.

Table 10.34 – Legislation and Assessment Guidance specific to Geomorphology and Coastal Processes

Document	Description
State Coastal Planning Policy No 2.6 (WAPC 2003)	The key objectives of the Policy that will apply are: ▸ Protect conserve and enhance coastal values, particularly in areas of landscape, nature conservation, indigenous and cultural significance. ▸ Provide for public foreshore areas and access to the coast. ▸ Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities. ▸ Ensure the location of coastal facilities and development takes into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change and biophysical criteria.

10.5.4 Potential Impacts

Potential impacts on geomorphology and coastal processes resulting from aspects associated with the proposed Outer Harbour Development are discussed below and summarised in **Table 10.35**. The key aspects that impact geomorphology and coastal processes are:

- the modification of the seabed and benthic substrate characteristics; and
- alteration of coastal hydrodynamic processes.

10.5.4.1 Modification of Seabed and Benthic Substrate Characteristics

Global Environmental Modelling Systems (GEMS) evaluated potential impacts to the geomorphology and coastal processes due to marine infrastructure and seabed disturbance associated with the proposed Outer Harbour Development (GEMS 2009). In addition, APASA evaluated the impacts of the causeway at West Creek on local hydrodynamics and resultant sediment distribution patterns. A report on this evaluation is included in **Appendix B4**.

GEMS established that the presence of mobile sedimentary features along the Port Hedland region of the coast is limited, principally associated with the Port Hedland Spoil Bank constructed from dredging activities in the 1960s, and a shallow beach perched on underlying rock at Cemetery Beach. The structure of coastal sedimentary features is typically aligned slightly north of east, suggesting a general eastwards transport of coastal sediments. There is a net supply of sediments from riverine sources, with very high sediment loads from the De Grey River (approximately 70 km north-east of Port Hedland), which has formed an extensive delta. Rocky features control the coastal processes in the region, including submerged offshore ridges, low cliffs along Finucane Island and fractured rock masses near Cooke Point, and strongly limit the mobility of sediment under wave and current conditions.

Establishment of the proposed channels (linking and departure) has the potential to increase localised sedimentation rates, as the deeper waters will create a depositional area in the locally shallow environment. The sedimentation rate for the channel has been estimated for this location as 250,000 m^3 per annum, however, when considering the coarse sediments generally involved, the 'best-estimate' is 160,000 m^3 per annum. This rate equates to a deposition of 10 to 16 cm of sediment over the seabed annually. This rate of sedimentation will create a thin veneer of soft sediments that are generally of coarse material. This will be a very similar habitat to the existing shallow sandy habitats that are well represented in the region, although at greater depths. As a result, the potential impact due to increased sedimentation rates in the channel is expected to be minimal.

Material removed from the seabed during dredging of the channels will be disposed at approved spoil grounds. While dredged material will be deposited within the spoil ground boundaries, the environment is such that the grounds will be dispersive meaning that over time spoil will gradually migrate away from the grounds. This migration will be due primarily to the influence of currents generated by tides. In effect, these currents will shave thin layers off the material in the spoil grounds. The net result will be a continuous, low level of material migrating from the spoil grounds across a broad region. As such, the potential impact to benthic substrate (e.g. smothering) lying outside of the spoil grounds due to the dispersion of dredged material is likely to be minimal.

Any change to the seabed has the potential to influence near shore wave climate. However, given the distance offshore and the minor reduction in water depth resulting from spoil disposal this is deemed to be negligible. The only wave heights or directions that might be altered would be under conditions where significant waves have been generated by severe storms or cyclonic conditions. Normal sea state would not generate waves that would have sufficient energy to reach the seabed in the depth of water present at the proposed spoil grounds thus the influence would not be significant. Modelling of this has not taken place due to the view that this was not a significant impact that required further predictive capacity.

10.5.4.2 Alteration of Coastal Hydrodynamic Processes

The presence of the proposed Outer Harbour Development infrastructure has the potential to interrupt sediment transport, with seasonal establishment of a sand lobe on alternating sides of the jetty abutment, and reduced tidal flows/infilling of West Creek.

The jetty abutment has been designed such that the majority of concrete and earthworks are above the high water mark. Below the existing limestone cliff, rock armoring will be necessary to protect the base of the structure during extreme weather events. Rock armoring will be parallel with the shore and extend approximately 10 to 15 m perpendicular from the existing cliff and 60 m wide along the beach. This structure will result in a small area, covering approximately 1 ha of the upper intertidal platform, being covered by the structure. The abutment has been designed to be parallel to the existing shore so that the potential sand build-up will be minimised (GEMS 2009). This sand lobe will only encroach on the very upper edge of the upper intertidal zone of the reef platform at Finucane Island. This zone of the intertidal reef platform has low biotic representation (refer **Section 6.6.2**) and as such, the potential impact due to the seasonal sand lobe that will locally accumulate around the abutment structure is likely to be minimal.

As discussed in **Section 10.1.4**, the proposed causeway over West Creek will influence the tidal flushing of the creek. APASA undertook a study into the impacts of the Outer Harbour Development on the tidal flushing of West Creek (**Appendix B31**). This study found that:

- impacts of the proposed development on both residual and maximum tidal currents within West Creek will be localised to the area surrounding the culverts along the proposed infrastructure corridor;
- impacts on the residual currents from the proposed development are localised to the area surrounding the culverts extending along the main channel of West Creek. The residual currents in these areas are increased but drop quickly with distance from the culvert locations; and
- the maximum current differences are also localised to the culvert locations.

The causeway will be designed such that culverts will maintain water flow during tidal exchange and therefore any change in the flushing regime will not be significant. Water flow through the culverts may cause temporary ponding of water behind the causeway when the tide is falling and delay inundation when the tide is rising. These effects are likely to be most noticeable during spring tides. A decrease in the flushing rate may cause sediments to accumulate on the seabed behind the causeway. In addition, slow moving water exiting through the culverts may result in additional sediment being deposited upstream of the culverts.

10.5.5 Management Measures

The proposed avoidance, mitigation, monitoring and contingency measures applicable to the management of impacts on geomorphology and coastal processes arising from the construction and operation of the proposed Outer Harbour Development are summarised in **Table 10.35**.

The engineering design of infrastructure has considered environmental impacts, including locating the transfer pad located sufficiently up the beach to minimise interruption to coastal process, and the provision of culverts in the causeway across West Creek.

10.5.6 Significance of Residual Impact

The key aspects of the proposed Outer Harbour Development that may impact geomorphology and coastal processes include the modification of the seabed through dredging and disposal leading to increased sedimentation rates in the newly created deeper waters, the interruption of coastal processes through establishment of infrastructure leading to a seasonal build-up of a sand lobe against the jetty abutment and infilling of West Creek due to alteration of tidal flushing associated with the causeway structure.

The interruption of sediment transport due to infrastructure has either been avoided or greatly minimised through the design of these structures and the integrity and ecological function of the seabed will be retained despite removal of material within the dredge footprint, and disposal of material in designated areas. As such, the significance of the residual impact of the proposed Outer Harbour Development on geomorphology and coastal processes is considered to be low.

10.5.7 Predicted Environmental Outcomes

The predicted environmental outcomes upon geomorphology and coastal processes as a result of the proposed Outer Harbour Development are:

State

- The EPA's objectives to maintain the integrity and stability of the coast, seabed and tidal creeks can be achieved.
- The EPA's objective to maintain the integrity, ecological functions and environmental values of the seabed and coast can be achieved.

Commonwealth

- There will be no impact to Matters of National Environmental Significance as a result of changes to geomorphology or coastal processes.

Table 10.35 – Summary of Potential Impacts Associated with Geomorphology and Coastal Processes

Environmental Aspect	Source	Impacts	Management
Seabed disturbance	Dredging of the channel and basin Disposal of dredged material at spoil grounds	Modification of seabed and localised alteration of seabed morphology through dredging leading to changes in geomorphology and coastal processes. Disposal of dredged material at dispersive spoil grounds leads to impact on the seabed in these areas.	*Avoidance/Mitigation/Management Measures:* A trestle structure has been used in the design of the jetty, allowing continuation of seasonal longshore sediment transport. Location of the proposed spoil grounds recognises the expected dispersive nature of the grounds by proposing them in areas generally surrounded by habitat that does not support many BPPs.
Physical presence	Permanent marine infrastructure (jetty, abutment, infrastructure crossing of West Creek)	Alteration of natural movement of sediment (erosion and deposition rates) potentially leading to enhanced erosion and alteration in coastline features generating impacts on critical habitats.	*Avoidance/Mitigation/Management Measures:* The placement and configuration of the jetty and abutment has been designed to avoid direct disturbance of marine BPPH due to construction, and indirect disturbance due to the annual appearance of literal drift.
		Alteration of geomorphology and coastal processes.	*Avoidance/Mitigation/Management Measures:* The infrastructure corridor causeway crossing West Creek will be designed to maintain tidal flushing at rates that cause minimal impact the flora and fauna upstream of the causeway.

10.6 Relevant Factor – Avifauna

The following section presents the assessment of impacts on shorebirds and seabirds associated with the project, taking into account impacts, and management and mitigation measures in both marine and terrestrial environments (**Sections 9** and **10**).

10.6.1 Management Objectives

The management objective that will be applied to the project for the environmental factor for shorebirds and seabirds is to:

- maintain their abundance, diversity, geographic distribution and productivity at species and ecosystem levels through avoidance or management of adverse impacts and improvement in knowledge.

10.6.2 Description of Factor

The project area provides suitable foraging habitat for species of seabirds and shorebirds within dunal, mangrove and tidal flat habitat areas on and around Finucane Island. Seabirds also utilise the shallow tidal channels and embayments along the coastline and the shallow coastal waters to forage.

Shorebirds (such as oystercatchers and some sandpipers, stilts, herons and bitterns, ibises and spoonbills and plovers), and seabirds (such as some eagles and kites, frigates and some shearwaters, gulls and terns) potentially occurring or recorded within the project area during fauna surveys (ENV 2009e, 2009f) are discussed in **Section 6.6.4**. Relevant key findings include:

- a total of 14 seabird species were observed, including 3 which are listed as migratory under the EPBC Act;
- a total of 26 shorebird species were observed, including 18 which are listed as migratory under the EPBC Act; and
- the project area is considered to have the potential to support a further 2 seabird species and 19 shorebird species which were not recorded during field surveys.

While the project area was not found to support large numbers of any of these species, it may be considered important habitat for migratory shorebirds due to the diversity of species recorded.

10.6.3 Assessment Guidance

Guidance on the assessment of impacts to shorebirds and seabirds exists at State and Commonwealth government levels. A summary of the assessment guidance documents relating to shorebirds and seabirds considered in this impact assessment is provided in **Table 10.36**.

10.6.4 Potential Impacts

Potential impacts on shorebirds and seabirds resulting from aspects associated with the proposed Outer Harbour Development are discussed below and summarised in **Table 10.37**. The key aspects that impact shorebirds and seabirds are:

- attraction, disorientation and deterrence;
- ingestion of inedible solid wastes;
- toxicity from leaks and spills; and
- removal of habitat.

10.6.4.1 Attraction, Disorientation and Deterrence

Light spill has been linked to attraction and possible disorientation of shorebirds and seabirds (Weise *et al.* 2001). Light spill will be generated during construction of the transfer station on Finucane Island, the infrastructure corridor, the jetty, wharf and shiploader as well as by marine vessels used during construction and operations.

Increased noise from construction and operation of the proposed Outer Harbour Development may deter shorebirds and seabirds from foraging in the area. Noise will be generated during dredging of the shipping channel and construction of the West Creek crossing and marine infrastructure. Major contributors to noise levels include vessel and vehicle movements, and machinery operation. Noise will be generated during operations by vessel movements and the shiploader.

Table 10.36 – Legislation and Guidance Documents Specific to Shorebirds and Seabirds

Document	Description
EPBC Act 1999 (Commonwealth Govt)	Addresses the protection of the environment, especially matters of National Environmental Significance (NES) and to conserve Australian biodiversity. The EPBC Act includes criteria for assessment of the significance of impacts to NES.
EPA Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002)	Outlines the EPA's consideration of biodiversity is the quality of the data provided, especially in relation to terrestrial biological surveys.
EPA Guidance Statement No. 56: Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia (EPA 2004b).	Outlines the EPA's consideration of biodiversity is the quality of the data provided, especially in relation to terrestrial fauna surveys.

Given the existing port developments on Finucane Island and the frequent presence of a large number of marine vessels offshore, it is considered likely that shorebirds and seabirds are accustomed to the types of lighting and noise generated in these areas.

10.6.4.2 Ingestion of Inedible Solid Wastes

A variety of solid wastes will be produced during the construction and operation of the proposed Outer Harbour Development. In the event of inappropriate disposal of these wastes to the marine environment, shorebirds and seabirds attracted to food scraps and sewage may ingest potentially harmful solid wastes (such as polystyrene containers or plastic bags) or may become entangled and potentially injured in solid debris.

10.6.4.3 Toxicity from Leaks and Spills

Leaks and spills into the marine environment may result from storage and transport of chemicals, fuels, or other hazardous material, or from the failure of equipment or pipelines. Such leaks and spills may prove toxic to shorebirds and seabirds if ingested or if they come into dermal contact. For instance, the external contact of shorebirds and seabirds with leaked or spilt hydrocarbons may reduce the birds' ability to waterproof feathers and subsequently regulate body temperature and buoyancy. Preening of feathers in contact with hydrocarbons may lead to ingestion.

Leaks or spills may also have a lethal effect on invertebrates in the area. As the mangroves and tidal flats surrounding Finucane Island provide a rich benthic invertebrate food source to shorebirds, this food source may be reduced or contaminated in the event of a leak or spill.

10.6.4.4 Removal of Habitat

Clearing of 26 ha of mangroves and 12 ha of tidal flat areas for the construction of the infrastructure corridor and transfer station will remove potential foraging and roosting areas for shorebirds and seabirds. The fauna surveys of the mangroves and tidal flats recorded no nesting sites and furthermore, revealed that the tidal flats lacked vegetation to support nests (ENV 2009e, 2009f). Therefore it is considered likely that the mangroves and tidal flats only constitute foraging habitat for shorebirds or seabirds and not breeding habitat. The dunal, mangrove, tidal flat and coastal waters utilised by shorebirds and seabirds are well represented within the local region. All of the species considered are highly mobile and have extensive home ranges, such that they are not considered to be reliant on habitat areas within the marine development footprint. For this reason, the anticipated loss of foraging habitat within the mangroves and tidal flats is expected to have a minimal impact on these species. For instance, the loss of 26 ha of mangrove habitat equates to a reduction of approximately 1% of the current aerial extent of mangroves in the Port Hedland Industrial Area (see **Figure 10.2**).

The closest site recognised as an important bird area by the DSEWPaC is the modified salt pans occupied by the Dampier Salt operations located approximately 5 km south-east of Port Hedland Harbour (DEWHA 2008a). Further offshore, Bedout Island serves as a rookery for some species of seabirds. Both areas are well away from the proposed project activities.

10.6.5 Management Measures

The proposed avoidance, mitigation, monitoring and contingency measures applicable to the management of impacts to seabirds and shorebirds arising from the construction and operation of the proposed Outer Harbour Development are summarised in **Table 10.37**.

Impacts on shorebirds and seabirds will be managed primarily through existing BHP Billiton Iron Ore controls. A number of preventative measures have been proposed to minimise the risk these aspects represent to seabirds and shorebirds using habitats in the project area including: strict waste control measures; minimise the clearing footprint as far as practical and demarcate areas to be cleared on plans and on-site; and minimise lighting required during construction and for security purposes (summarised in **Table 10.37**).

10.6.6 Significance of Residual Impact

Given that the small area of habitats to be impacted is generally well represented in the local area, regional representation of habitats will not be significantly reduced. Surveys of avifauna in the project area and regional surrounds by ENV (2009e, 2009f) have noted that although the area to be affected is accessed by some shorebird and seabird species for feeding, no nesting has been observed in these areas. Therefore, the seabirds and shorebirds occurring in the area are not reliant on the habitats in the project footprint for nesting, and foraging resources in the regional area are well represented. Risks to avifauna through ingestion and exposure to wastes and hazardous materials will be greatly minimised through waste management and spill prevention and response planning.

As a result, it is considered that it is highly unlikely that there will be a significant impact on avifauna at a local, population or ecological level.

10.6.7 Predicted Environmental Outcomes

The predicted environmental outcomes for avifauna as a result of the proposed Outer Harbour Development are:

State

- The EPA's objective to maintain avifauna's abundance, diversity, geographic distribution and productivity at species and ecosystem levels through avoidance or management of adverse impacts and improvement in knowledge will be achieved.

Commonwealth

- It is unlikely that there will be a significant impact to any avifauna listed as "Endangered, Vulnerable and Migratory" under the EPBC Act.

10.7 Matters of National Environmental Significance

Matters of National Environmental Significance (NES) exist in relation to the presence of marine fauna in the project area. Matters of NES relevant to marine fauna are defined as:

- listed threatened species and ecological communities;
- migratory species protected under international agreements; and
- the Commonwealth marine environment.

Three species listed as vulnerable under the EPBC Act have been identified as present within the project area:

- Green Turtle;
- Flatback Turtle; and
- Humpback Whale.

Two species listed as migratory under the EPBC Act have been identified as found within the project area however no resident populations are known to occur in the area:

- Dugong; and
- Spotted Bottlenose Dolphin.

Management and mitigation measures proposed for marine fauna will carefully consider the vulnerable species categorised as matters of NES.

Within the proposed Outer Harbour Development area, protected marine fauna have been recorded and may potentially occur. A complete list of the protected marine fauna that may occur in the proposed Outer Harbour Development area is provided in **Appendix B28**. Provided here is a focussed consideration of protected marine fauna that in particular may be susceptible to the marine habitat impacts detailed above.

Dugongs are known to occur in the proposed Outer Harbour Development area and are protected under the EPBC Act. The one area of seagrass habitat (86 ha) observed in the development area was not observed to have feeding scars present at the time of investigation, however there is a high likelihood this habitat supports feeding dugongs. No loss or serious impacts are proposed or predicted for this seagrass habitat.

Marine turtles are also known to occur in the proposed Outer Harbour Development area and are protected under the EPBC Act. Marine turtle feeding studies identified that the species foraging in the development area have a varied diet including sponges, macroalgae and soft corals. Although these benthic organisms are widespread in the proposed Outer Harbour Development area, marine turtles were observed to feed at particular locations including North Turtle Island and adjacent to De Grey River mouth. None of these locations are proposed or predicted to experience habitat losses or serious impacts due to the proposed Outer Harbour Development.

The Olive Sea Snake has been observed in the proposed Outer Harbour Development area and several other species of sea snake may occur in this region. Sea snakes will utilise subtidal reef habitat for foraging. Total proposed losses of hard substrate due to the proposed Outer Harbour Development amount to 147.6 ha. Accounting for this habitat loss, over 40,600 ha of hard substrate will remain post-completion of the proposed Outer Harbour Development construction activities. The remaining hard substrate habitat occurs in extensive and contiguous structures that are underpinned by limestone ridgelines traversing hundreds of kilometres throughout and beyond the development area. For those fauna disrupted due to habitat losses required for foraging, alternative habitats will be available, supporting similar benthic communities to those that will be impacted.

Further consideration of impacts to marine fauna is provided in **Section 10.4**.

Two birds listed as 'endangered' and 'vulnerable' under the EPBC Act were identified as potentially occurring in the project area:

- Endangered: Southern Giant-Petrel (*Macronectes giganteus)*; and
- Vulnerable: Australian Painted Snipe (*Rostratula australis)*.

A further thirty-one 'Migratory' birds listed under the EPBC Act potentially occur in the project area and broader region, either flying over or using habitats

Table 10.37 – Summary of Potential Impacts and Management Actions Associated with Shorebirds and Seabirds

Environmental Aspect	Source	Impacts	Management
Light spill	Construction and operational vessels, marine infrastructure (jetty, wharf and shiploader) and terrestrial infrastructure (transfer station, West Creek crossing).	Attraction and possible disorientation.	*Avoidance/Mitigation/Management Measures:* ▸ Lighting required during construction and for security purposes will be minimised. ▸ Flood lights will utilise lighting with an asymmetric distribution (i.e. focused lighting) to avoid unnecessary light spill into fauna habitats.
	Permanent infrastructure on or near Finucane Island.	Deterrence of potentially nesting shorebirds or seabirds on Finucane Island.	*Avoidance/Mitigation/Management Measures:* ▸ Key infrastructure, such as stockyards, rail loop, infrastructure corridor, transfer station, where practicable will be located in or adjacent to previously disturbed areas.
Liquid and solid waste disposal	Domestic wastes and treated sewage from vessels and marine infrastructure.	Ingestion of solid wastes. Attraction to food scraps.	*Avoidance/Mitigation/Management Measures:* ▸ A clean, rubbish-free environment will be maintained, particularly around administration and contractor areas in order to discourage scavenging and reduce the potential for colonisation of vermin.
		Injury due to entanglement in solid waste.	
Leaks and spills	Storage and transport of chemicals, fuels or other hazardous material. Failure of equipment or pipelines.	Toxicity to birds through external contact or ingestion.	*Avoidance/Mitigation/Management Measures:* ▸ Appropriate storage and handling of chemicals, fuels and other hazardous material. ▸ Spill contingency plans prepared to manage refuelling, storage and spill management. ▸ Spill response kits located in close proximity to storage areas for prompt response in an event.
Noise	Vehicle movement and machinery operation.	Deterrence of potentially nesting shorebirds or seabirds on Finucane Island.	*Avoidance/Mitigation/Management Measures:* ▸ Measures put in place to control noise emissions for public amenity will also apply to seabirds and shorebirds (refer to **Section 11**).
Clearing and earthworks	Clearing of mangroves and intertidal mudflats for construction of infrastructure corridor and transfer station.	Direct loss of habitat used for nesting or foraging.	*Avoidance/Mitigation/Management Measures:* ▸ Minimise the clearing footprint as far as practical and demarcate areas to be cleared, and the project approved footprint, on plans and on-site. ▸ Implement an environmental awareness training program. *Monitoring:* ▸ Mangrove mapping will be undertaken at completion of the project. *Contingency Measures:* ▸ If mangrove clearing occurs outside of the approved project footprint, mangrove clearing activities will be temporarily stopped until the outcomes of an investigation into the non-approved clearing have been concluded.

found in the region (e.g. Port Hedland salt works and offshore islands); and a further 48 'Marine' listed birds, of which 31 birds as also included above as 'Migratory' under the EPBC Act, potentially occur in the project area.

These species have been described further in **Section 6.6.4**. None of the data-base listed 'Migratory' species are associated with or dependant on the terrestrial habitats of the project area and it is therefore considered that impacts from the project will significantly affect EPBC Act listed fauna species at and surrounding the project.

The closest location to the project which is considered an important bird area by the DSEWPaC is the modified salt pans occupied by the Dampier Salt operations. The pans are approximately 5 km south-east of Port Hedland Harbour (DEWHA 2008a).

10.8 Summary

The proposed Outer Harbour Development will require 54 Mm^3 of sediment and rock material to be dredged and disposed of in the ocean. At the peak of development activities, 40 construction vessels will be in operation in the marine waters offshore of Port Hedland. At these specifications, the proposed Outer Harbour Development will be the biggest marine development undertaken in the Pilbara region.

Predicted impacts to marine factors which may experience potential impacts of noteworthy importance are summarised below:

- **Marine Water and Sediment Quality**: marine water and sediment quality will be impacted during construction dredging activities. Impacts will be confined to the proposed dredging periods and the management and monitoring measures proposed will lead to a reduction in the extent and severity of impacts. Dredged material to be disposed of at spoil grounds 3, 7 and 9 is considered acceptable for unconfined ocean disposal. Following the completion of construction activities, the return of ambient marine water and sediment quality conditions within the project area is expected. During operation of the marine facilities, compliance with the moderate LEP (90% ecological protection) boundary, as proposed for areas around existing wharves, jetties and ship turning basins will be required.
- **Marine Habitat**: direct and indirect losses of marine habitat will result from the proposed Outer Harbour Development and the BPPs supported by this habitat including mangroves (total area: 27.0 ha; cumulative area: 155.1 ha; cumulative loss: 5.7%; loss threshold: E – 10%), coastal intertidal habitat (total area: 1.7 ha; cumulative area: 70.7 ha; cumulative loss: 14.2%; loss threshold: E – 10%) and subtidal BPPH in State waters (total area: 147.9 ha; cumulative area: 167.1 ha; cumulative loss: 2.2 to 52.9%; loss thresholds: E – 10%). Although the proposed loss areas are sizeable, the project will not reduce the local or regional representation of these communities, and impacts to ecosystem function are not predicted. Measures in the Mangrove Management Plan (**Appendix A2**) and the Dredging and Spoil Disposal Management Plan (**Appendix A3**) will be implemented to minimise predicted and potential impacts.
- **Marine Fauna**: the area contains some significant marine fauna including endangered and vulnerable species, but these species are either distributed widely throughout the entire region and appear to be interconnected within it, or they occur in, or utilise, areas which do not lie near Port Hedland. The exception is the presence within the area of populations of four turtle species. A number of aspects of the proposed Outer Harbour Development have the potential to impact marine fauna including light spill, noise/vibration, inappropriate disposal of liquid and solid waste, clearing and earthworks, leaks, spills and discharges from vessels and infrastructure. Assessment of potential impacts to marine fauna found that aspects of the proposed Outer Harbour Development construction and operational phases will not result in population impacts, and risks to individuals can be effectively managed through the Marine Turtle Management Plan (**Appendix A1**), Dredging and Spoil Disposal Management Plan (**Appendix A3**) and Marine Mammal Management Plan (**Appendix A4**).
- **Geomorphology and Coastal Processes**: dredging and construction activities will alter the existing configuration of the Port Hedland nearshore environment, and alter tidal flows in West Creek with the construction of a causeway. Through engineering design measures, such as placement of infrastructure and dredge spoil, and the design features of infrastructure (e.g. culverts within the West Creek Crossing), the risk to coastal processes is considered low.

The marine factor which may experience potential impacts of minor or negligible consequence is summarised below:

- **Avifauna**: a number of aspects of the proposed Outer Harbour Development have the potential to impact shorebirds and seabirds including light spill, noise/vibration, inappropriate disposal of liquid and solid waste, clearing and earthworks, leaks, spills and discharges from vessels and infrastructure. Preventative measures proposed by the Construction Environmental Management Plan and identified sub-management plans will minimise the risk to seabirds and shorebirds (e.g. strict waste control measures; minimise the clearing footprint as far as practical and demarcate areas to be cleared on plans and on-site; and minimise lighting required during construction and for security purposes).

It is concluded that the potential cumulative impacts on the marine environment from the proposed Outer Harbour Development can be managed through the comprehensive measures contained within the Construction Environmental Management Plan and identified sub-management plans. Through implementing these plans the EPA's environmental objectives can be met.