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# Section 6
# Existing Marine Environment

# 6 Existing Marine Environment

## 6.1 Overview

Port Hedland lies on the central Pilbara coast, which is described as tropical arid zone (BoM 1989). The Pilbara coast lies at the centre of the North-West Marine Region (DEWHA) 2008), which extends from the Western Australian-Northern Territory border to Kalbarri in the south. The characteristics of the marine environment in this coastal setting are defined by connectivity with the wider Indo West Pacific biogeographic region and the suite of geological, geomorphological, tidal and climatic features that determine the scale and distribution of marine habitats present.

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

The Port Hedland Port Authority (PHPA) port covers an area of approximately 42,000 ha, encompassing the Inner Harbour and the Outer Harbour defined by a 10 nautical mile (nm) radius off Hunt Point to the high water mark at the shoreline (PHPA 2006) (**Figure 6.1**). The Inner Harbour is generally shallow, with a natural maximum water depth of 9 m chart datum (CD). Historical dredging of an approach channel, turning basin and berthing pockets has considerably changed the bathymetry of the Inner Harbour (PHPA 2008a). The Outer Harbour has also been disturbed by the dredging of a shipping channel, creation of several offshore spoil grounds and the deposition of spoil material into a large sand bar that has now become a prominent feature of the town of Port Hedland's coastline (see **Section 6.8**).

The marine infrastructure and dredged shipping channel for the proposed Outer Harbour Development is planned to extend approximately 40 km offshore, encompassing areas within and beyond the existing PHPA port limits. Within the PHPA port limits, the marine development footprint traverses areas of intertidal habitat including mangroves and creek channels. It also traverses rocky intertidal, shallow water sand habitats in the nearshore areas north of Finucane Island and deeper areas further offshore for the proposed spoil grounds, departure and link channels. The conceptual layout for the proposed marine infrastructure is presented in **Figure 6.1**.

Groundwater abstracted from the site of the car dumpers will be discharged into a branch of Salmon Creek, on the western side of the existing causeway (**Figure 2.2**). The proposed discharge point is approximately 500 m downstream of the approved discharge location for water from BHP Billiton Iron Ore's Rapid Growth Project 5 (RGP5) Dredge Material Management Area A (DMMA A). The receiving environment surrounding the proposed discharge location is a narrow mangrove-lined channel which experiences strong diurnal tidal flushing, leading to scouring of the creek banks (BHP Billiton Iron Ore 2008f). The creek bed surrounding the proposed discharge point is exposed to air on low tide, although some shallow, permanent pools are present. A habitat mapping study conducted by SKM (SKM 2009t) did not detect any subtidal benthic primary producers (BPP) of significance in this branch of Salmon Creek.

## 6.2 Oceanography

The Indonesian Throughflow and the Leeuwin Current are the signature currents of the North-West Marine Region because of their influence on the ecology of the region (DEWHA 2008). Connectivity with waters of the Indonesian Archipelago and the western Pacific is provided by the Throughflow. The water is modified by the passage through the Indonesian seas of freshwater inputs and run-off from high rainfall over Indonesia, causing these waters to become increasingly warm, oligotrophic (high in oxygen or low in nutrients) and of low salinity (DEWHA 2008).

Port Hedland is located within the North-West Shelf Province (DEWHA 2008). The North-West Shelf Province, one of eight provinces within the North-West Marine Region, extends across both State and Commonwealth waters and is located in a transitional climatic region between the dry tropics to the south and the humid tropics to the north (average rainfall in Broome is twice that of Port Hedland). The surface waters of the bioregion are tropical year-round, with summer sea surface temperatures around 26°C, and winter temperatures around 22°C (DEWHA 2008).

### 6.2.1 Circulation

The Indonesian Throughflow Current delivers warm, low-nutrient and low-salinity water from the western Pacific Ocean to the Indian Ocean. These waters are predominantly southward moving surface waters that circulate throughout the area via branches of the South Equatorial and Eastern Gyral Currents, and consolidate along the continental shelf break to form the Leeuwin Current (Domingues *et al*. 2007).

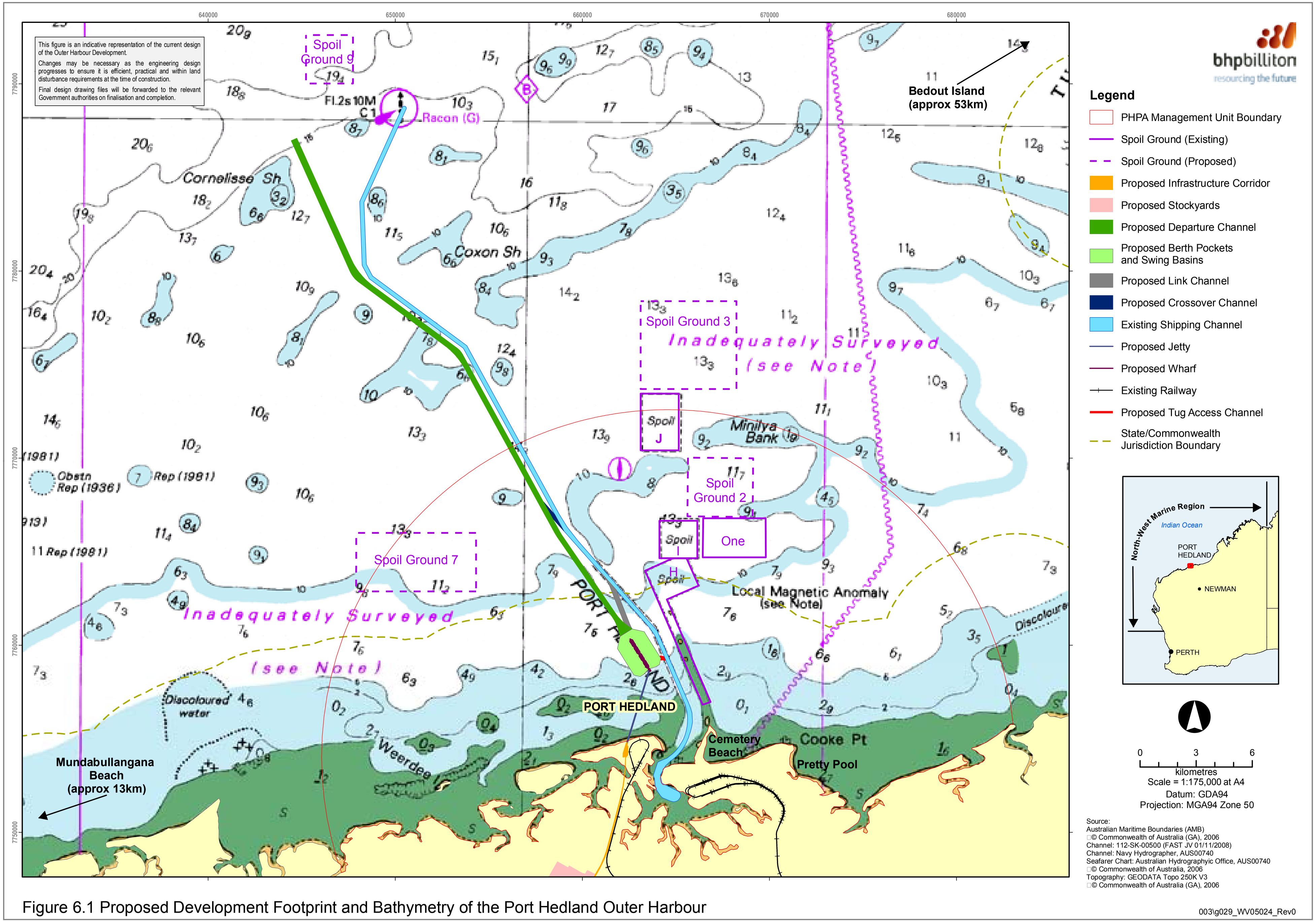



Figure 6.1 Proposed Development Footprint and Bathymetry of the Port Hedland Outer Harbour

Large-scale currents, such as the Leeuwin Current, have little impact in the nearshore region in this area, being typically stronger and more coherent south of 22.5° S latitude (Godfrey & Ridgeway 1985) and centred on the continental shelf (approximately 200 m isobath). The limited influence of the Leeuwin Current potentially reduces the interannual variability of water circulation patterns, as large-scale currents are known to be strongly correlated to irregular El Niño Southern Oscillation (ENSO) events (APASA 2009a).

### 6.2.2 Tides and Currents

The coastal oceanographic system of the region is tidally dominated in the nearshore waters, by the large semi-diurnal tidal regime. The highest astronomical tide (HAT) is 7.9 m and typically ranges from 1.5 m depth during neaps to 6 m depth at springs (PHPA 2003). These large tides drive oscillating currents of around 1 m/s (2 knots) that can increase in the entrances to the numerous tidal creeks along the coastline. The direction of tidal currents is typically aligned north-west to south-east across the local bathymetric contours (APASA 2009a).

Wind is the secondary forcing mechanism for local currents, and typically drives persistent, residual flows along the coastline. A slight dominance in the strength and persistence of west to north-westerly winds during the spring and summer months (wet season) typically results in a long-term drift towards the east and north-east, following the coastline. Weaker and less persistent current reversals occur during times of northerly and easterly winds during autumn (transitional period) and winter (dry season) (APASA 2009a).

For most of the year there is a relatively calm wave regime, usually with less than 1 m background swell. Between December and May (wet season), the Pilbara region is subject to sporadic, intense storms and an average of three to four cyclones occur each season (CSIRO 2008). Cyclones have affected Port Hedland on average about once every two years, with seven severe (Category 3 or greater) cyclones recorded since 1910 (BoM 2008). One of the most significant cyclones to have affected Port Hedland was Cyclone Joan which crossed the coast 50 km west of Port Hedland in December 1975 and achieved wind gusts of up to 208 km/h (BoM 2009b).

Under cyclonic conditions, strong currents and possibly extreme waves may significantly alter the tidal-driven circulation and act to resuspend previously settled material, subsequently dispersing it over a larger region. Cyclonic events and subsequent land flooding produce large influxes of freshwater run-off into the coastal marine environment, which are likely to lead to large-scale sediment plumes in the nearshore waters carried from onshore (APASA 2009a).

## 6.3 Coastal and seabed geomorphology

### 6.3.1 Coastal Geomorphology

The Port Hedland area is a limestone barrier coast (refer to **Section 5.3** for a detailed description of the landforms, geology and soils of the terrestrial study area). The combination of offshore limestone ridges and the large tidal range produces protected embayments, sandy substrates with mangroves, mud flats, wide salt flats and a number of islands and associated reefs. Regional-scale coastal processes and tropical arid climatic conditions interact to produce these diverse coastal landforms (Semeniuk 1993; Environ 2004) (**Section 5.2**).

Swell waves and locally generated waves produce coastal landforms such as beaches (including Mundabullangana Beach, Cemetery Beach, Pretty Pool and Cooke Point; **Figure 6.1**) 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 (Gilmour *et al*. 2006).

Coastal landforms in the marine development footprint include a sandy beach and low limestone cliff near the location of the proposed jetty abutment 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.

### 6.3.2 Bathymetry and Seabed Geomorphology

The seabed level in the Port Hedland region deepens gradually with distance from the coastline, by approximately 0.5 to 1 m every kilometre. The wharf head and turning basins for the proposed Outer Harbour Development are located 4 km from the seaward edge of Finucane Island in water depths of approximately 7 to 9 m CD (**Figure 6.1**). The outermost point of the proposed departure channel, which is approximately 34 km in length from the proposed wharf head and turning basins, is at a depth of approximately 20 m CD. Throughout the marine study area, shore-parallel ridge lines are present where the water depth of the surrounding sand plain seabed is generally 10 m CD or greater.

The peaks on some ridges rise to a depth of 6 m CD. The proposed shipping channel will run mostly parallel to the existing departure channel, which is aligned at right angles to these ridgelines.

The seabed in the vicinity of the proposed jetty consists of a low relief limestone platform covered by shallow sediments in the inshore area. Approximately 2 km offshore, there are shallow limestone areas where the seabed slopes gently out to the proposed wharf location. At the proposed wharf location the depth increases from 5 m to approximately 9 m CD. A thin layer of unconsolidated coarse sandy sediment covers much of the seabed in the marine development footprint, including the areas of the wharf, departure channel, turning basin and proposed spoil grounds (SKM 2009e, **Appendix B20**). This layer is less than 3 m thick throughout and less than 1 m thick for a large portion of the marine development footprint (Fugro 2006). Underlying this layer are variable thicknesses of calcarenite pavement (1 to 2 m), clays, weakly cemented gravels and soft sandstones.

Bathymetric charts available for the region were not sufficiently detailed for the purposes of this project, as indicated on **Figure 6.1**. To provide more accurate bathymetric information, an aerial survey was undertaken using light detection and ranging (LiDAR) over an area of approximately 365,000 ha (**Figure 6.4**) (Tenix 2008). This technique enabled the refinement of dredging alignments, selection of spoil ground locations, and detailed identification and mapping of areas where different benthic habitats might be situated. The area encompassed by the LiDAR survey is referred to as the 'study area' for the marine investigations described in this section.

### 6.3.3 Fate of Dredged Material

Numerical modelling of dredge spoil disposal onto a spoil ground is used to predict the effects of turbidity generated by the act of disposal and subsequent resuspension, and thus the fate of the material over a given time. This includes the effects of severe forces such as seasonal cyclonic activity periodically experienced in the Port Hedland region. The best example of the fate of dredge spoil in the Port Hedland area is at Spoil Ground J (**Figure 6.2**) which received material in 1985 of a similar composition to that proposed by this project. The dumping pattern remains clearly visible over the area even after 25 years and after the action of many cyclones and the action of waves and currents.

Like this project, approximately 10% of the material was in the particle size range of 0–130 μm. This size fraction is created by the physical breakup of the material being dredged and is the major component of the overflow from the dredger. This can be seen in **Figure 6.3** which shows the particle size distribution of overflow water from a trailer suction hopper dredger (TSHD) that has been used to pick up material crushed by a cutter suction dredger (CSD).

Of particular interest is the fate of the various size fractions. Numerical modelling predicts that the distance from the dumping location where deposition of material will take place will decrease with increased particle size. This means that the finer the material the greater the distance taken for it to drop (settle) out of the water column and reside on the seabed. It also means that the finer the material the more easily it will be resuspended. The action of storm events that resuspend this fine material will have the effect of shifting it out of the shallow coastal areas into deeper offshore areas where it will settle and be less likely to be resuspended. **Figure 6.3** demonstrates the movement of a given quantity of fine material in the overflow water from the dredger.

Approximately 35% of the material in the size range 0–5 μm will not settle out of suspension until it is well offshore and in deep water. In depths of greater than 100 m, forces affecting its suspension in the water column are sufficiently reduced that it can finally settle out. Material in the size range 5–20 μm accounts for 30% of the material overflowed and this is likely to settle out over a distance of 10 km from the source of suspended particles (dredger or spoil ground). The remaining 35% is predicted to settle out over a distance of 1 km. The predicted distances are based on settling velocities and the tracking of these particles by numerical modelling programs (pers. comm., Graeme Hubbert, Global Environmental Modelling Systems (GEMS)).

The dumping pattern shown in **Figure 6.2** would be the resultant material less the fine particle sizes that would have been resuspended and been transported offshore into deeper water. However, it is quite clear that the majority of the material (approximately 90%) has remained *in situ* and has not spread beyond where it was originally deposited. Deposition of material in this project is predicted to have the same fate. Once on the spoil ground, disposed material will remain *in situ* and, depending upon the intensity and frequency of storm events, only the very fine material will be carried away to be deposited offshore in deep water (in excess of 100 m).

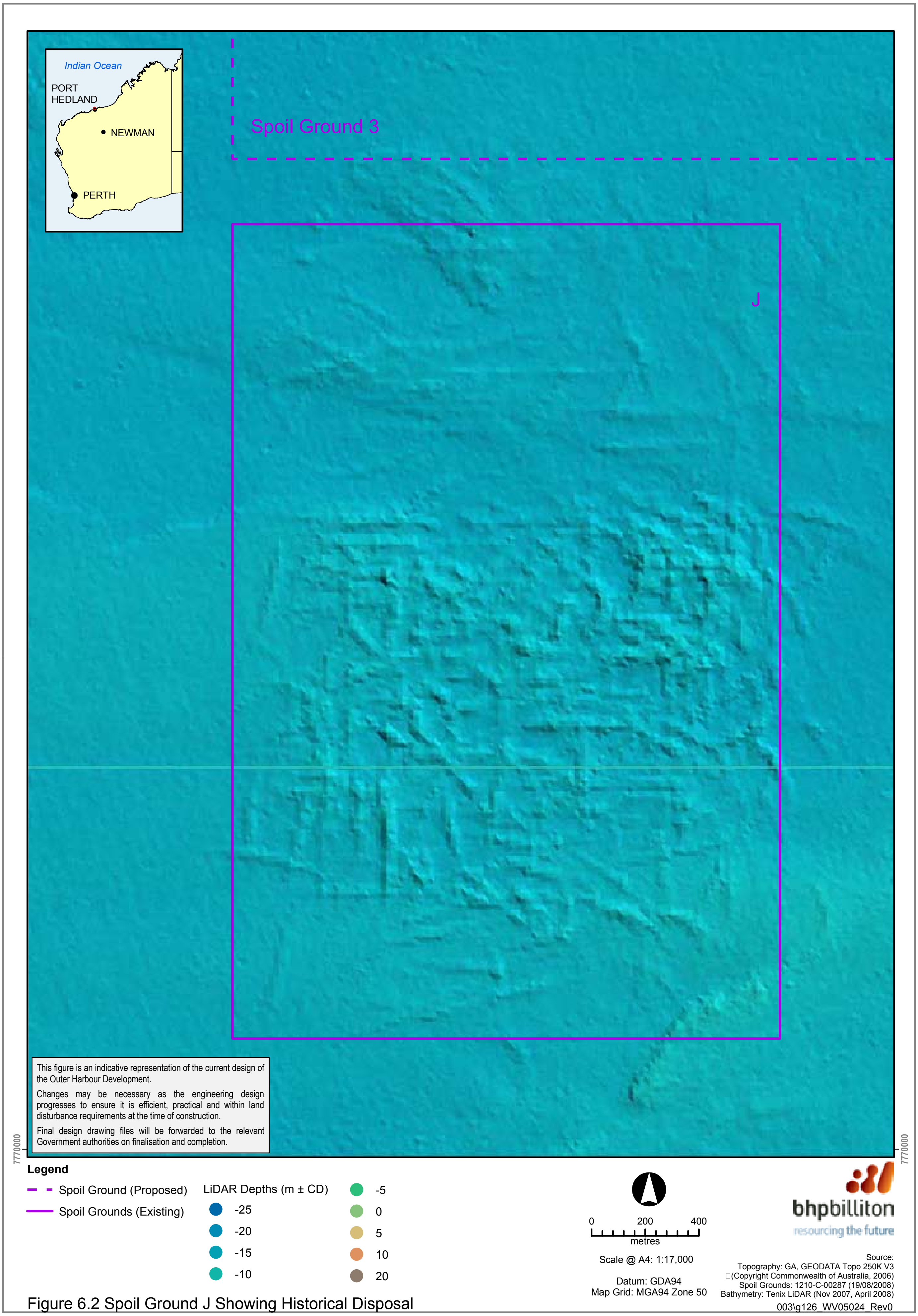
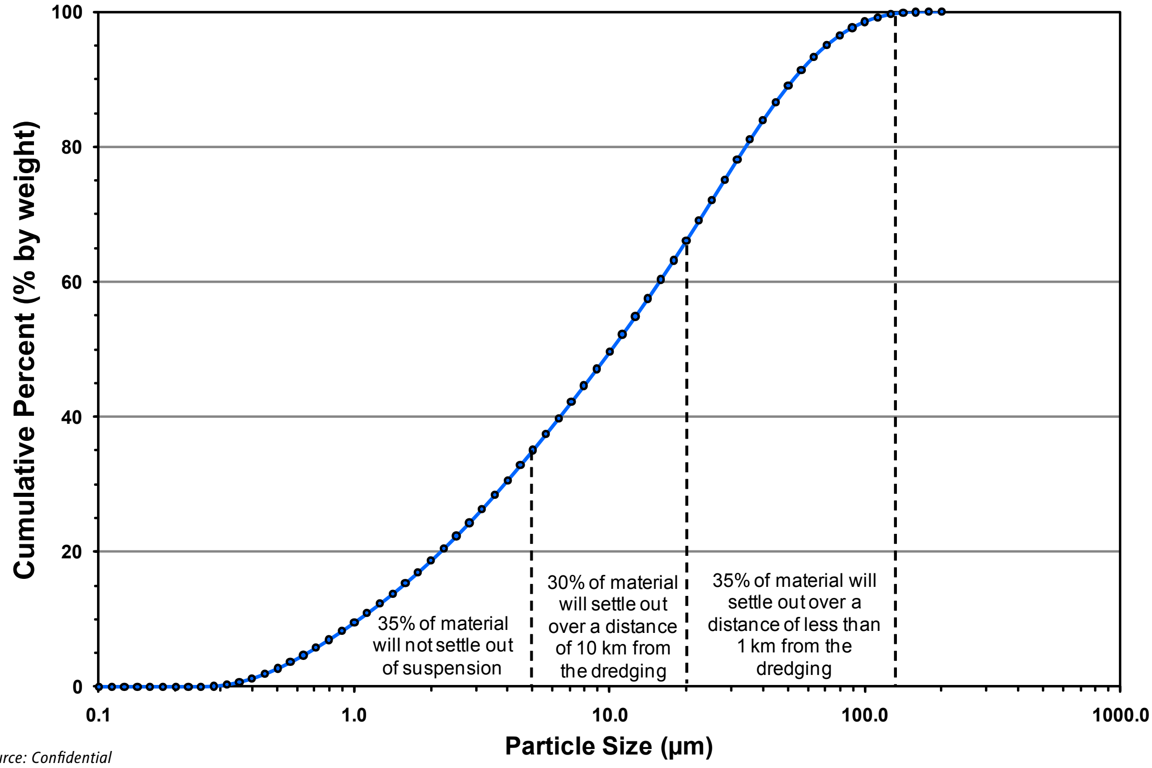



Figure 6.2 Spoil Ground J Showing Historical Disposal

**Figure 6.3 – Particle Size Distribution of Overflow Water from a Trailer Suction Hopper Dredger**




*Source: Confidential*

## 6.4 Water Quality

This section provides a summary of the results that are presented in detail in **Appendix B10 and B19** (SKM 2009f).

Six sites were selected for baseline water quality and coral health monitoring (**Table 6.1** and **Figure 6.4**) based on the existing information provided by preliminary plume modelling results, LiDAR survey results, field surveys of benthic habitat and field observations of environmental characteristics. The sites were distributed across the study area, and included hard coral communities representative of the study area. Results from baseline monitoring led to the delineation of three water quality zones based on water depth and distance offshore, as illustrated on **Figure 6.4**. These are not intended to indicate Local Assessment Units (LAUs) (in regards to the Environmental Assessment Guideline No.3 on BPPs (EPA 2009b)), which are described in **Section 10**.

The baseline water quality data highlighted large temporal and spatial variations in light, turbidity[1], water temperature and sedimentation. Much of the observed variability was attributable to season, weather, tides and distance offshore. There was a distinct seasonal transition in light, turbidity and sedimentation rates from the dry (June to November) to the wet season (December to May). The turbidity variability at all sites increased with the onset of the wet season, and the light climate decreased. The sedimentation rates at all sites increased from November to January. This was to be expected with the transition from the dry to wet season as the highest levels of sedimentation followed acute periods of strong winds and waves as a result of storms and cyclones. All results observed were within the range of previous water quality observations made during other studies within the Pilbara region (SKM 2009q, MScience 2007).

### 6.4.1 Turbidity

Turbidity was measured at each site, as increased turbidity reduces the amount of light reaching corals. This can lead to stress by reducing the rates of photosynthesis of coral zooxanthellae (Gilmour *et al*. 2006). **Table 6.2** provides descriptive statistics[2] for turbidity (measured as NTU[3]) over the wet and dry seasons and the combined seasonal values over the entire 12 months of the baseline monitoring period. Turbidity data varied spatially between sites and temporally between and within sites during

1 Turbidity is a measure of the amount of light scatter caused by suspended materials in the water column.
2 Descriptive statistics are used to provide an understanding of the behaviour of data. The descriptive statistics used are dependent upon the distributional nature of the data: for parametrically distributed data the mean and standard deviation are used to describe central tendency and variability, while for non-parametrically distributed data the median and percentiles are used.
3 The unit of measurement for turbidity is nephelometric turbidity units (NTU). In contrast, total suspended solids (TSS) is a measure of the mass of suspended solids in the water column.

**Table 6.1 – Water Quality Monitoring Sites**

| Site | Code | Description | Approximate mid-tidal water depth (m) | Latitude | Longitude |
|---|---|---|---|---|---|
| Weerdee Ridge | WIS | Inshore | 5 | 20° 17.414' S | 118° 28.893' E |
| Cape Thouin | CTH | Midshore | 8 | 20° 14.995' S | 118° 17.194' E |
| Minilya Bank | MIB | Midshore | 10 | 20° 09.002' S | 118° 38.157' E |
| Little Turtle Island | LTI | Midshore | 10 | 20° 01.081' S | 118° 47.991' E |
| Coxon Shoal | COX | Offshore | 13 | 20° 03.998' S | 118° 27.485' E |
| Cornelisse Shoal | COR | Offshore | 12 | 20° 02.040' S | 118° 22.560' E |

baseline monitoring. Median turbidity was low at all sites over the baseline monitoring period (less than 2 NTU). At the offshore and midshore sites, 80% of measurements were less than 2 and 4.6 NTU, respectively. Turbidity at the inshore site was less than 6 NTU.

The median turbidity at all sites over both seasons was low (less than 2 NTU); however, the range of values was higher during the wet season than the dry season for each site. This is consistent with typical background turbidity levels measured previously in the Pilbara, which are generally higher during summer months (the wet season) due to storms and cyclones (Gilmour *et al*. 2006).

Sediment resuspension occurred more readily in nearshore to midshore waters (depths between 5 to 10 m CD) during major tidal changes or strong winds, compared to offshore locations or deeper waters (greater than 10 m CD). Nearby estuaries and land-based run-off during the outgoing tide deposit fine material in the inshore areas, further increasing turbidity (Gilmour *et al*. 2006).

### 6.4.2 Water Temperature

For the duration of the baseline monitoring, the water temperature was similar across sites and responded to seasonal changes in air temperature. Water temperature decreased during the cooler months of June to August, reflecting the decline in ambient air temperature characteristic of the winter season. Water temperature then steadily increased during the summer months. The offshore, warm, south-flowing Leeuwin Current does not appear to impact the monitoring locations and therefore has apparently little or no effect on the water temperature in the monitored region. As a result, water temperatures dropped substantially in winter by over 6°C.

Fluctuations in temperature were more evident in shallow waters, where the smaller water volume was more readily influenced by tidal changes, level of sunlight and wind factors. The greatest range in water temperature occurred at the inshore site of Weerdee Ridge (17.3 to 33.7°C), followed by the midshore sites of Cape Thouin (18.5 to 32.9°C), Little Turtle Island (18.5 to 32.6°C) and Minilya Bank (19.1 to 32.8°C). The range

**Table 6.2 – Descriptive Statistics for Turbidity (NTU) at the Six Monitoring Sites during the Dry and Wet Seasons**

| Description | Site Name | Dry Season (June – November) NTU | | | Wet Season (December – May) NTU | | | Baseline Monitoring Period (Wet and Dry) NTU | |
|---|---|---|---|---|---|---|---|---|---|
| | | n[1] | Median | 80th %ile | n[1] | Median | 80th %ile | Median | 80th %ile |
| Nearshore | Weerdee Ridge | 8,250 | 1.4 | 4.6 | 7,477 | 1.0 | 8.9 | 1.3 | 6.0 |
| Midshore | Cape Thouin | 8,758 | 0.7 | 1.7 | 7,456 | 1.1 | 10.7 | 0.8 | 3.3 |
| | Minilya Bank | 8,505 | 0.9 | 2.1 | 8,321 | 1.5 | 9.6 | 1.1 | 4.3 |
| | Little Turtle Island | 8,774 | 1.8 | 3.7 | 7,698 | 1.9 | 6.5 | 1.8 | 4.6 |
| Offshore | Cornelisse Shoal | 7,363 | 0.5 | 1.1 | 6,241 | 0.8 | 2.5 | 0.6 | 1.8 |
| | Coxon Shoal | 8,317 | 0.4 | 0.8 | 7,293 | 0.7 | 5.5 | 0.5 | 1.8 |

*1 n = Total number of measurements for a given site.*

was smallest at the offshore sites of Cornelisse Shoal (19.9 to 31.3°C) and Coxon Shoal (20.1 to 31.7°C).

### 6.4.3 Light Availability

Light availability was measured approximately 50 cm above the seabed at the six monitoring sites as this is the approximate height at which light would influence coral growth. Measurements demonstrated that periods of reduced light availability relative to the maximum light available during summer occurred throughout June to September 2008, typically coinciding with episodes of increased wind activity and greater tidal extremes (**Table 6.3**).

High winds and tidal regimes have the potential to promote sediment resuspension and subsequently reduced light penetration. However, light penetration is also influenced by water depth and therefore, despite being more turbid, the shallower, tidal and wind influenced inshore areas had higher levels of total light per day.

Extended periods of daylight and increased light intensity accompanied the transition from winter to spring, resulting in increased light availability in the inshore waters. Offshore, where the large tidal range had less influence and turbidity was more stable, light availability was more consistent.

### 6.4.4 Sedimentation Rate

Sedimentation was monitored at each of the six monitoring sites to determine the volume of organic and inorganic material that is naturally deposited onto benthic habitats. Gross sedimentation rate was measured using sediment traps deployed at each site over approximately fortnightly periods for the 12-month baseline study, and a daily rate for the dry and wet seasons was calculated as the mean rate per day (mg/cm$^2$/d). Gross sedimentation measures the amount falling into the sediment trap and cannot account for the natural re-suspension of sediment that is subsequently picked up by the tidal currents or wave action and transported away from the site. However, the cylindrical design of the sediment trap minimises the sediment loss and standardises the measure.

The mean gross daily sedimentation rate was much higher at the inshore site of Weerdee Ridge (93.4 to 322.7 mg/cm$^2$/d; in the dry and wet seasons, respectively) compared to other sites. The lowest mean gross daily sedimentation rates were recorded at the offshore sites of Coxon and Cornelisse Shoals (6.4 to 18.0 mg/cm$^2$/d; for dry and wet seasons, respectively; **Table 6.4**).

The mean gross daily sedimentation rate increased at all sites from November to January, with the greatest increase occurring in December reflecting the onset of the wet season. The inshore and midshore sites (shallower sites), Weerdee Ridge and Cape Thouin, showed the largest increase in mean gross daily sedimentation rates between dry and wet seasons.

### 6.4.5 Sediment Particle Size Distribution

Sediment particle size distribution was determined for each site. High levels of large particles have the potential to impact on coral health by smothering and high levels of fine particles may

**Table 6.3 – Descriptive Statistics for Light (moles/m$^2$/d) at the Six Monitoring Sites during the Dry and Wet Seasons**

| Description | Site Name | Dry Season (June – November) NTU | | | Wet Season (December – May) NTU | | | Baseline Monitoring Period (Wet and Dry) NTU | |
|---|---|---|---|---|---|---|---|---|---|
| | | n1 | Median | 80th %ile | n1 | Median | 80th %ile | Median | 80th %ile |
| Nearshore | Weerdee Ridge | 183 | 8.0 | 12.3 | 183 | 4.9 | 7.9 | 6.3 | 10.4 |
| Midshore | Cape Thouin | 183 | 7.6 | 10.6 | 168 | 5.7 | 8.6 | 6.6 | 9.9 |
| | Minilya Bank | 183 | 4.2 | 5.8 | 182 | 2.5 | 4.4 | 3.5 | 5.4 |
| | Little Turtle Island | 183 | 2.6 | 5.3 | 182 | 1.8 | 4.0 | 2.2 | 4.6 |
| Offshore | Cornelisse Shoal | 183 | 6.4 | 8.0 | 167 | 3.7 | 5.4 | 5.0 | 7.1 |
| | Coxon Shoal | 183 | 5.1 | 6.6 | 156 | 2.3 | 4.7 | 4.0 | 6.0 |

1 n = Total number of measurements for a given site.
Note: unit of moles per metre squared per day of Photosynthetically Active Radiation is considered the most appropriate measure of light in the context of primary producers, as the SI unit for light, candela, is measured with reference to the human eye and as such has little relevance to primary producers.

stay in suspension and reduce light available to corals (Gilmour *et al*. 2006). Sediment particle size distributions were calculated at each of the sampling sites for material from both the sediment trap and from the top 2 cm of natural seabed sediment. Particle size distribution analyses indicated the material in the sediment traps was mostly fine (at least 70% dry weight was less than 150 µm at any site) whereas the material adjacent to the sediment traps was mostly coarse (more than 90% dry weight of material was from 150 µm up to more than 500 µm at any site) (SKM 2009f).

These data suggest that at all sites fine material is settling from the water column, but once settled it is quickly re-suspended and does not accumulate on the seabed. As the material present at each site is relatively coarse it can be inferred that the majority of fine sediment collected inside the sediment traps has been transported to the site from elsewhere.

## 6.5 Sediment Quality

This section provides a summary of the physical and chemical characteristics of sediments in the offshore region of Port Hedland. For further detail on sediments, refer to **Appendix B6**.

### 6.5.1 Physical Characteristics

The physical characteristics of the sediments in and around the dredging footprint were investigated using surficial sediment cores and geotechnical boreholes (SKM 2009e) as well as visual inspections by divers (SKM 2009k).

Offshore sediments are considered to be those that lie in Commonwealth waters, mostly deeper than the 5 m bathymetry contour and include the Inner and Outer Channel footprints. Visually, the dominant physical seabed surface sediment types were medium to coarse grain sand and shell fragments (SKM 2009k). These sediments were comprised of mostly very fine gravel and very coarse sand with some coarse sand (SKM 2009e).

Nearshore sediments are those within State waters up to the HAT mark. Visually, the dominant physical seabed surface sediment types were medium to coarse grain sand and shell fragments (SKM 2009k). These sediments were comprised mostly of very coarse sand with some fine gravel and coarse sand (SKM 2009e).

### 6.5.2 Chemical Characteristics

The proposed dredging footprint commences approximately 4 km offshore, in an area distant from potential land-based and industrial contaminant inputs. The nearest potential sources of contaminants to the sediments within the proposed dredging footprint are the existing shipping channel 1 km to the east and the entrance to the Inner Harbour, approximately 5 km south-east.

There has been no previous spoil disposal within the proposed dredging footprint, and existing spoil grounds (H, I and J) lie adjacent to this area (**Figure 6.4**). The lack of nearby sources of contaminants indicates that it is unlikely that sediments are contaminated from anthropogenic sources.

Disposal of dredged material for sea dumping is governed by the Commonwealth *Environment Protection (Sea Dumping) Act 1981* which is under

**Table 6.4 – Descriptive Statistics for Mean Gross Daily Sedimentation Rate ($mg/cm^2/d$) at the Six Monitoring Sites during the Dry and Wet Seasons**

| Site Name | Dry Season (June – November) | | | Wet Season (December – May) | | |
|---|---|---|---|---|---|---|
| | n[1] | Mean | S.D.[2] | n[1] | Mean | S.D.[2] |
| Weerdee Ridge | 24 | 93.4 | 49.8 | 32 | 322.7 | 474.0 |
| Cape Thouin | 24 | 11.5 | 6.2 | 32 | 129.5 | 210.4 |
| Minilya Bank | 24 | 9.0 | 7.5 | 33 | 37.8 | 54.6 |
| Little Turtle Island | 24 | 19.4 | 13.4 | 33 | 30.9 | 20.5 |
| Cornelisse Shoal | 24 | 7.4 | 4.0 | 30 | 18.0 | 14.1 |
| Coxon Shoal | 24 | 6.4 | 4.3 | 30 | 27.9 | 36.2 |

1 n = Total number of measurements for a given site. There were three replicate sediment traps per site, with 8 sample periods of 14 days duration in the dry season and 11 sample periods in the wet season (some replicate samples were lost for 4 of the sites in the wet season).
2 S.D. = standard deviation

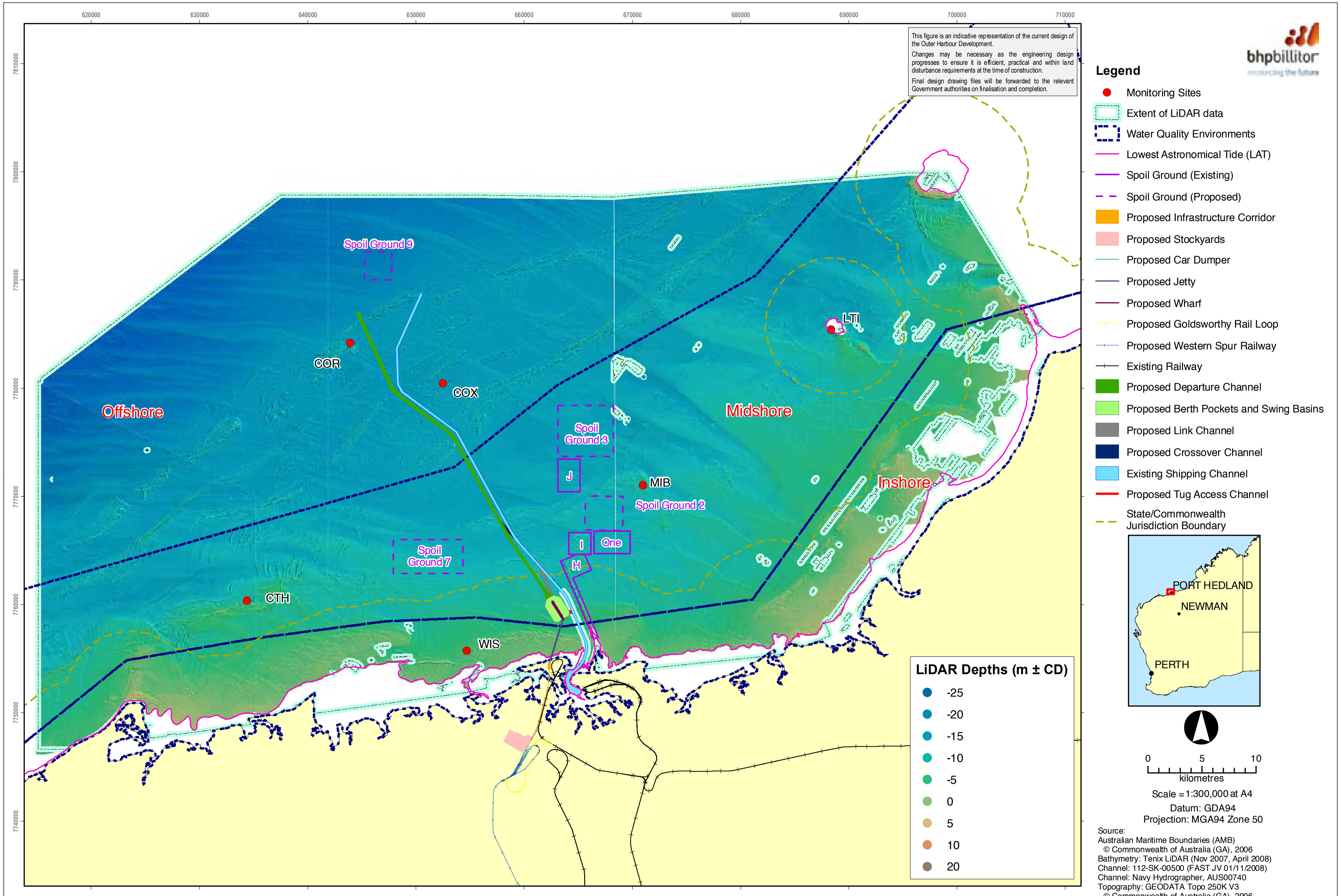



Figure 6.4 Water Quality and Coral Health Baseline Monitoring Sites and Zoning

the jurisdiction of the Department of Sustainability, Water, Environment, Population and Communities (DSEWPaC[1]). The process of assessing the suitability of the dredged material for unconfined ocean disposal for the proposed Outer Harbour Development was undertaken using the National Ocean Disposal Guidelines for Dredged Material (NODGDM) (Environment Australia 2002). These Guidelines are applicable as the assessment was conducted prior to the release of the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia 2009), which replaced the NODGDM in February 2009.

A detailed Sampling and Analysis Plan (SAP) for the proposed Outer Harbour Development was prepared to assess sediment quality and its suitability for unconfined ocean disposal under the NODGDM (Environment Australia 2002). The SAP was approved for implementation by the DEWHA on 8 October 2008.

The SAP identified the likely contaminants of concern, based on a regional assessment and proposed a sampling regime to test for these potential contaminants. It also identified any additional analyses required to characterise sediment as suitable for dredging and spoil disposal. The contaminants of concern that were identified in the SAP by a detailed literature search of sediment quality analyses in the Port Hedland Harbour were:

- metals including arsenic, cadmium, chromium, copper, lead, manganese, nickel, and zinc; and
- the ship anti-foulant tributyltin (TBT).

The complete list of analyses performed on samples included:

- metals including antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, silver and zinc;
- TBT and total organic carbon;
- particle size distribution and moisture content; and
- polycyclic aromatic hydrocarbons, organochlorines and polychlorinated biphenyls.

The SAP was implemented and the results compiled into the SAP Implementation Report (SKM 2009e) provided in **Appendix B3**[2].

Surficial sediment samples taken from a total of 213 sites were analysed for the contaminants listed above. Of these, 60 were collected to the west of the proposed dredging footprint, as part of a pilot study undertaken during conceptual engineering design. Seventy-seven sites were within or immediately adjacent to the dredging footprint; and 18 were located in the final three preferred spoil ground locations (**Figure 6.5**). The remaining sites were within the now discounted spoil ground options (refer to **Appendix B20**). In addition, material was analysed within two to three strata from each of ten geotechnical boreholes taken to dredging depth within the proposed dredging footprint. The geotechnical core sampling was undertaken to characterise deeper sediments and to ensure that no contaminants of concern existed at depth.

A summary of the findings includes:

- Arsenic (95% upper confidence limit (UCL)) was found in surficial material in all areas investigated at levels of 30.4 mg/kg, which is above the NODGDM screening level (20 mg/kg) but below the NODGDM maximum level (70 mg/kg). The exception was at Spoil Ground 7 which had slightly higher levels than the NODGDM maximum level (70.1 mg/kg). Arsenic is believed to be a naturally-occurring element in the sediments and base material of the region (DEC 2006b). The material contained arsenic at levels above the NODGDM screening levels but comparable to background levels indicating that the material was of natural origin. Accordingly, no further testing was considered necessary beyond this stage.
- Arsenic (95% UCL) was 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. Arsenic is believed to be a naturally-occurring element in the sediments and base material of the region (DEC 2006b) and subsequent testing indicated that it was neither bioavailable nor toxic.
- Chromium (95% UCL) was found at 45.5 mg/kg to a depth of 19 m in boreholes, which did not exceed the NODGDM screening level (80 mg/kg). Chromium 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.

1 Previously Department of Environment, Water, Heritage and Arts (DEWHA) – http://www.environment.gov.au
2 The SAP Implementation Report provides a complete list of the NATA accredited laboratory analyses results.

- Nickel (95% UCL) was found at 24.2 mg/kg to a depth of 19 m in boreholes, which exceeded the NODGDM maximum level (52 mg/kg), 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 (<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 dredge footprint 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.
- 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.

Based on sediment analysis results, 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 Appendix F of that report: *Geotechnical Environmental Sampling and Analyses*). Although arsenic, chromium and nickel were measured in the sediments, these are believed to be naturally-occurring (DEC 2006b) and were also found in the background material (pilot study) of the study area and in boreholes of undisturbed base material and are therefore not considered to be contaminants of anthropogenic origin. The NODGDM (Environment Australia 2002) consider that the material is clean if the contaminants are below the screening level; or for naturally-occurring materials, concentrations should not be more than twice the background level of the receiving environment (i.e. the spoil grounds). The metals were found to be non-bioavailable and non-toxic indicating that the metals are bound to the sediments and unlikely to be released into the water column during dredging and disposal. These metals do not pose a risk to the environment if mobilised during dredging and disposal.

Although the material contained arsenic at levels above the NODGDM screening levels (20 mg/kg), concentrations were comparable to background levels indicating that the material was of natural origin. No further testing was required as the material to be dredged was classified as clean or uncontaminated and suitable for unconfined ocean disposal. In addition, ecotoxicity testing of sediment elutriate samples using a suite of five species reported no toxicity.

The proposed spoil grounds (**Figure 6.5**) are considered to be clean of contaminants as per the definition in NODGDM (Environment Australia 2002); however, all three demonstrated high naturally-occurring arsenic levels. Arsenic is naturally-occurring throughout the Pilbara marine region (DEC 2008b) and is not a risk to the ecology of the area at the measured concentrations. The spoil grounds have similar sediment chemistry and physical properties to that of the area to be dredged. In addition, the areas within the proposed spoil grounds are sparsely populated or devoid of benthic macro invertebrates and BPPs such as hard corals (SKM 2009g).

## 6.6 Biological Environment

### 6.6.1 Marine Habitats Overview

Port Hedland lies within the North-West Shelf Province (DEWHA 2008), a vast bioregion between North West Cape and Cape Bougainville that encompasses much of the area more commonly known as the North-West Shelf. It covers an area of 23,875,900 ha.

The size of the province reflects the recognition of the presence of very similar physical conditions throughout the shallow coastal waters of the North-West Shelf. Not surprisingly, the marine habitats present are also widely distributed throughout the province, and the majority of species supported within these habitats are common to many areas within the province and within the wider Indo-West Pacific bioregion.

There are differences between areas within the province but in general the ubiquity of geological features, oceanography, bathymetry and prevailing climatic conditions means that many habitats that are common to the entire area, show local trends which reflect local geomorphological processes (Semeniuk 1993).

The North-West Shelf Province is located almost entirely on the continental shelf, except for a small area to the north of Cape Leveque that extends onto the continental slope. The shelf gradually slopes from the coast to the shelf break, but displays a number of seafloor features such as banks/shoals and holes/valleys (DEWHA 2008). Much of the seabed over large areas within the province is similar, dominated by carbonate sands, particularly south of Broome. The distribution of flora and fauna associated with these sedimentary habitats is likely to be largely

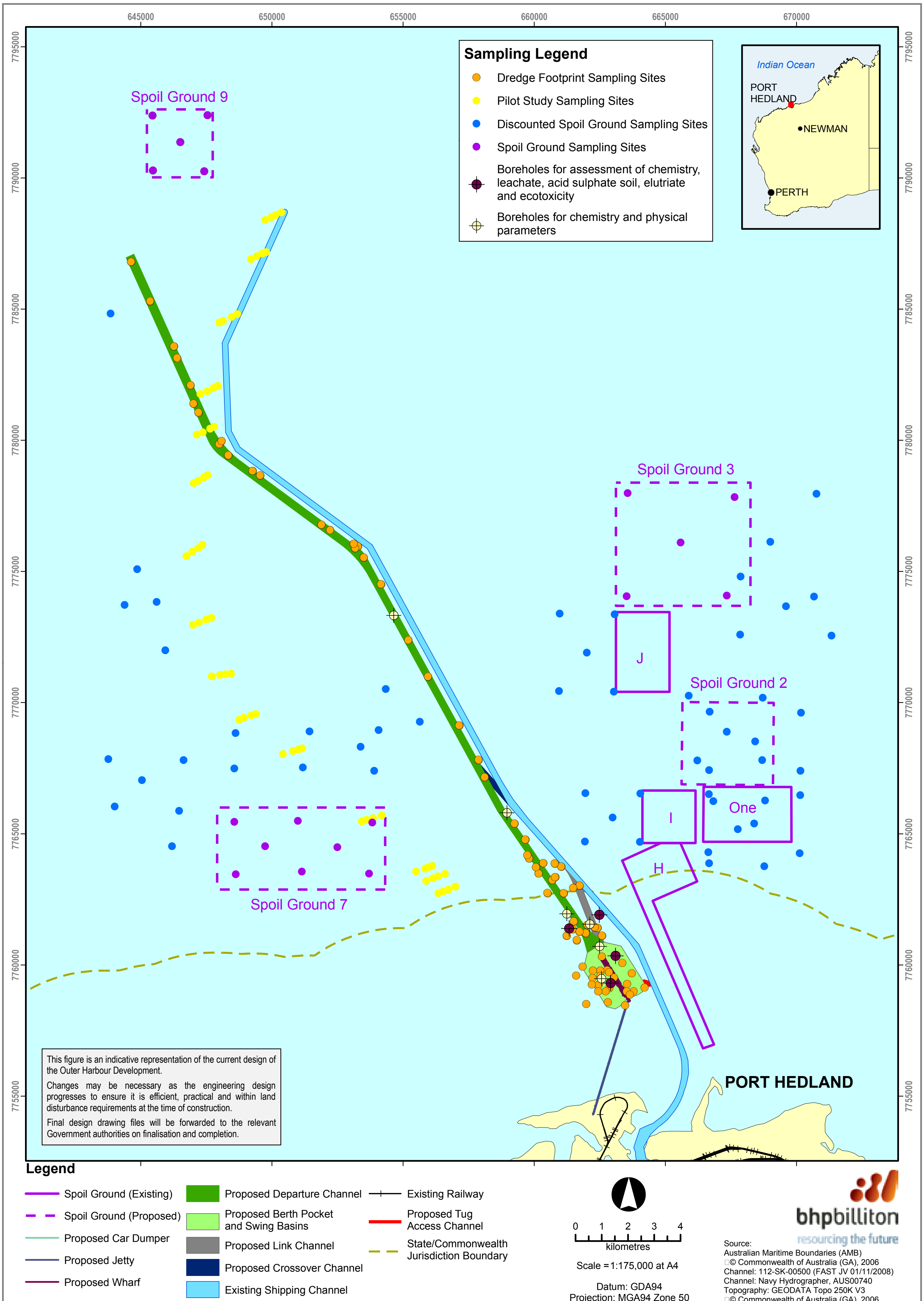



Figure 6.5 Location of Sediment Sampling Sites and Spoil Grounds

related to changes in sediments with increasing depth, with coarser grades of material dominant in the shallower areas closer to the coast, particularly where macrotidal conditions occur.

Cyclones influence sediment distribution throughout the province and the seafloor is particularly strongly affected by cyclonic storms, long-period swells and large internal tides, which can resuspend sediments within the water column as well as move sediment across the shelf (DEWHA 2008).

Much of the coast throughout the province is relatively exposed, although areas near where shelter is afforded by peninsulas (e.g. Mermaid Sound located approximately 197 km south-west of Port Hedland Harbour, North-West Cape located approximately 488 km south-west of Port Hedland Harbour and Cape Lambert located approximately 150 km south-west of Port Hedland Harbour) tend to accumulate a broader range of sediments (e.g. fine silts and muds). Consequently, the range of marine habitats present in such areas is broader than those typically found on the more open sections of coastline (Wolanski *et al*. 2005).

Shoals, reefs and islands occur throughout the province, and all are geological features that were flooded (shoals and reefs) or isolated (islands) by the Holocene marine transgression.

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 marine study area have been applied in the following impact assessment:

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

Benthic habitats extend from the high water mark of the intertidal zone, through to all areas of the subtidal zone (SKM 2009j). **Section 6.6.2** discusses the marine habitats dominated by BBPs.

**Intertidal Habitats**

Intertidal marine habitats were surveyed during several field visits and with the aid of aerial photography to assist in site selection. Results were extrapolated to areas that were inaccessible (SKM 2009j, 2009k). High resolution images were then used to map the intertidal mangrove and salt marsh (or samphire) habitats including the present and historical extent of these habitats (SKM 2009j).

Intertidal habitats in and around Port Hedland are characterised by sand and mud flats with mangroves and salt marsh supporting samphires. Dense stands of mangroves occupy the lower intertidal zones where tidal inundation is sufficiently frequent to maintain adequate sediment water content and salinity levels. As distance from the creek channels increases, the height and cover of vegetation decreases and mangroves become more sparse, eventually being replaced by salt marsh and areas of bare tidal flats, as sediments become drier and more saline (Saenger 2002).

Some areas between the mangrove and samphire-dominated habitats of the upper intertidal zone support cyanobacterial mats when conditions are suitable (Paling *et al*. 1989, 2003). Cyanobacteria are blue-green algae that obtain their energy through photosynthesis. There are many aquatic and terrestrial forms of cyanobacteria. The genera *Oscillatoria*, *Phormidium* and *Microcoleus* that have been observed in the Pilbara region (Paling 1986) are widespread in these habitats. Cyanobacteria are an important component of the nitrogen cycle, as they fix atmospheric nitrogen.

Some intertidal areas, such as the seaward side of Finucane Island, are characterised by low rocky cliffs and sandy beaches with rocky intertidal platforms supporting a mix of macroalgae and marine invertebrates. The diversity and abundance of biota in these habitats is considered to be highly variable as this area is occasionally covered by sand, on a seasonal basis and/or as a consequence of random events such as cyclones.

**Subtidal Habitats**

Baseline surveys of subtidal marine benthic habitats in the Port Hedland region were undertaken between December 2007 and May 2008 (SKM 2009g, **Appendix B21**). The area surveyed (the marine study area) was extensive, covering approximately 365,000 ha (50 km to the east and west of Port Hedland Harbour and 40 km seaward) and included 343 survey locations. LiDAR investigations highlighted seabed relief likely to support benthic habitat. Habitat information was collected either by divers making observations and taking replicated 50 m video transects, or by towing video cameras over longer transects. The locations for the diver or video surveys (**Figure 6.6**) were selected after examining the detailed LiDAR seabed bathymetry, bathymetric charts and aerial photographs of inshore areas.

The results of the subtidal surveys show that benthic habitats offshore of Port Hedland comprise extensive plains of sand/silt, and limestone pavement and ridges (SKM 2009g). Many of the offshore limestone ridges run parallel to the coastline, and those areas of ridges surveyed support sparse hard corals, macroalgae, soft corals, gorgonians, sea whips and sponges. The extensive plains surveyed are often bare of any large marine flora or fauna (such as coral and macroalgae), and mainly support smaller sediment dwelling invertebrates and very sparse sponge and soft coral assemblages. Macroalgae occur on both hard and soft substrata and their abundance varies among different habitats and according to season. Seagrasses are not common in the Port Hedland area and those that do occur are ephemeral species such as *Halophila ovalis* that form patches of low to medium density (**Section 6.6.2**). The homogeneity of benthic habitats observed across the study area, and the continuity of similar seabed bathymetry outside the study area, suggest that areas outside the study area would support similar benthic habitats (refer Australian Hydrographic Chart AUS326).

### 6.6.2 Benthic Primary Producer Habitat

BPPs are reliant on sunlight to convert carbon to organic compounds via photosynthesis. BPPs are predominantly marine plants such as seagrasses, macroalgae and mangroves, but also include invertebrates such as hard (scleractinian) corals that acquire much of their energy from symbiotic microalgae living in the coral polyps (EPA 2004c).

Benthic primary producer habitat (BPPH) is defined herein as areas of seabed (both subtidal and intertidal) that support or are capable of supporting BPPs. Therefore, BPPH is the substrate upon which BPPs can or do grow.

The following sections provide a summary of the intertidal and subtidal BPPH[1] in the Port Hedland region and the range of BPPs present. Further detail is included in **Appendix B21** and **Appendix B22.**

#### Intertidal Benthic Primary Producers

Habitat maps of existing intertidal benthic primary producers within the Port Hedland Harbour Industrial Area Local Assessment Unit[2] were produced using published information, and supplemented with aerial photography and results of ground truthing surveys (**Figure 6.7**).

The intertidal zone is dominated by tidal flats fringing a tidal creek system and the intertidal benthic primary producers present are predominantly mangroves, with salt marsh (samphires) and cyanobacterial mats present at higher levels on the shore.

*Mangroves*

Mangroves are a diverse, highly-specialised group of salt-tolerant plants that share the ability to live in waterlogged soils and have adapted to the unique and often harsh environmental conditions in which they live (Duke 2006). Mangroves are most common in tropical and subtropical regions.

The geographical distribution of mangrove habitat is typically restricted to sheltered areas such as estuaries, tidal creeks and sheltered bays. The mangroves along the Pilbara coastline are all widespread species (Duke 2006) both within northern Australia and the wider Indo-West Pacific region. However, the mangrove species present along the Pilbara coast typically exhibit different growth forms compared to other areas due to the arid conditions where a lack of reliable fluvial influence and high evaporation rates restrict the potential areas of the intertidal zone suitable for colonisation by mangroves.

Seven species of mangrove have been recorded within the Port Hedland Industrial Area LAU (**Table 6.5**), all of which are found elsewhere in the Pilbara region and none are listed as threatened under the EPBC Act or the WC Act. The western white mangrove (*Avicennia marina*) and the stilt mangrove (*Rhizophora stylosa*) are the most abundant species throughout the study area. The smooth-fruited yellow mangrove *(Ceriops australis)* is locally abundant on the south-western shores of Finucane Island, typically forming a distinct but narrow band of varying width along the hinterland margin. The remaining four species are relatively uncommon within the study area and are usually found as isolated individuals or as small stands of several trees in front of, or on the landward edge, of the associations formed by the more common mangrove species.

1 Intertidal benthic primary producer habitat for the project is defined as occurring between the highest and lowest astronomical tide level, and subtidal benthic primary producer habitat is defined as occurring below the lowest astronomical tide level and offshore to the extent of the study area.
2 Port Hedland Industrial Management Unit is a 'local assessment unit' (LAU) previously defined under the EPA Guidance Statement No1 (2001) for the protection of tropical arid zone mangroves along the Pilbara coastline.

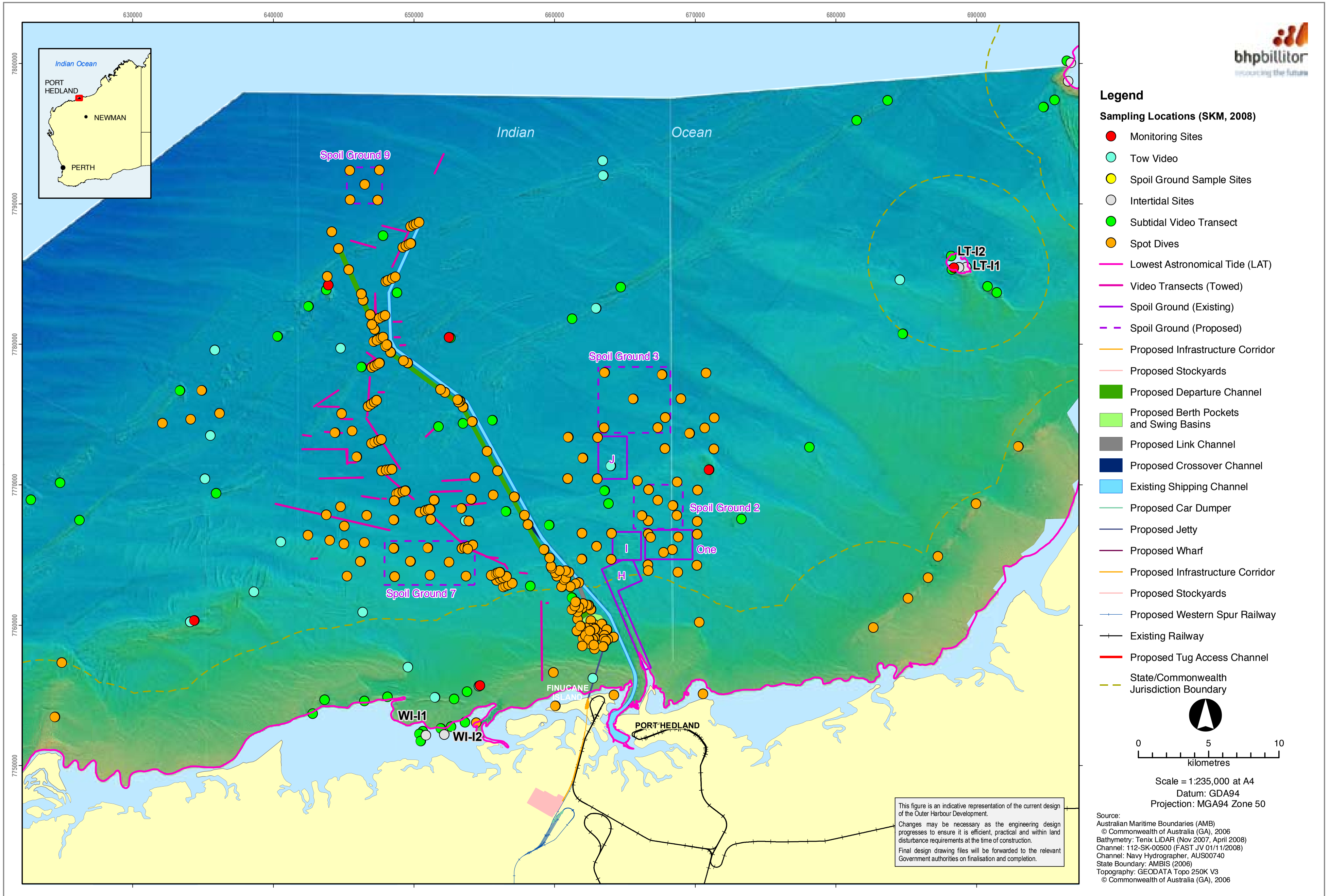



Figure 6.6 Location of Subtidal Investigations

The mangrove habitats of the study area can be classified into a number of categories, based on the mangrove associations described by Semeniuk (2007) and Paling *et al.* (2003). A map showing the distribution, and photographic examples, of the mangrove associations that together comprise the mangrove BPPs are provided in **Figure 6.7**. The mangrove association classifications used here are:

1. *Avicennia marina* (scattered) – comprising scattered individuals of the mangrove *Avicennia marina*, often with scattered samphires, but without high densities.
2. *Avicennia marina* (closed canopy, landward edge) – a forest/scrub comprising the typical zone of mangroves immediately behind the mixed association of *Avicennia marina* and *Rhizophora stylosa* and often up to 100 m in width or more and characterised by a decrease in vegetation height with increasing height on the shore.
3. *Avicennia marina/Rhizophora stylosa* (closed canopy) – a forest/scrub comprising a transitional zone between closed canopy forest adjacent to the seaward edge of main channels and extending landward along small channel banks.
4. *Rhizophora stylosa* (closed canopy) – a forest/scrub comprising a relatively thin zone often only a few trees wide behind the seaward *Avicennia marina* fringe and also lining steep banks on small channels.
5. *Avicennia marina* (closed canopy, seaward edge) – a forest comprising large, mature, multi-stemmed *Avicennia marina* on the seaward edge of the main channels and also sheltered small bays.

Other mangrove associations such as the narrow seaward fringe of *Aegiceras corniculatum*, the landward edge fringes of *Ceriops australis*, and the mixed associations of *Avicennia marina*, *Ceriops australis*, *Aegialitis annulata*, *Bruguiera exaristata* and *Osbornia octodonta*, are not readily depicted in **Figure 6.7** at the scale of mapping displayed due to their narrow and scattered distribution (SKM 2009l).

The mangrove trees of the closed canopy zones and particularly larger trees, appears to be critically important to some bird species in providing suitable niches. Johnstone (1990) documents eight species of passerine songbirds that are largely dependent on mangroves in the Pilbara region, where the mangroves form the only closed canopy forest in the region. All eight species of bird are able to utilise more than one type of mangrove and they typically forage widely in all mangrove vegetation types; some also use samphires and tidal flats.

In addition, the marine affiliated bat species, the Little North-western Freetail Bat (*Mormopterus loriae cobourgensis*) utilises the mangroves within the study area and greater regional areas. This species of bat was identified during two fauna surveys (summer and winter) by ENV (2009e, 2009f).

Based on previous surveys of the mangrove habitats undertaken in the vicinity of the proposed Outer Harbour Development, for Inner Harbour projects (SKM 2009l) (**Appendix B23**), the characteristics of the mangrove habitats were mapped at Finucane Island and the south bank of West Creek, where the mangroves are proposed to be impacted by construction activities.

**Table 6.5 – Mangrove Species in the Port Hedland Harbour**

| Scientific Name | Common Name |
|---|---|
| *Aegialitis annulata* | Club mangrove |
| *Aegiceras corniculatum* | River mangrove |
| *Avicennia marina var. marina*[1] | Western white mangrove |
| *Ceriops australis*[2] | Smooth-fruited yellow mangrove |
| *Osbornia octodonta* | Myrtle mangrove |
| *Rhizophora stylosa* | Long-style stilt mangrove |
| *Bruguiera exaristata* | Large leafed orange mangrove |

1 Previously reported as *Avicennia marina* (the grey or white mangrove) but now assigned to *Avicennia marina* var. *marina* (the western white mangrove) by Duke (2006), with a distribution from Bunbury to Broome.

2 Previously reported as *Ceriops tagal*, but a recent review by Duke (2006) has concluded that the closely related *C. australis* is the only species of the genus present on the Western Australian coast.

Finucane Island

The western tip of the large bay on the southern side of Finucane Island supports a high diversity of mangrove species relative to other surveyed areas. This area contains the mangrove species *Avicennia marina*, *Ceriops australis*, *Rhizophora stylosa*, *Aegialitis annulata*, *Aegiceras corniculatum Bruguiera exaristata* and *Osbornia octodonta* (SKM 2009l). A single specimen of *Aegiceras corniculatum* was recorded at one survey site (SKM 2009l). *Aegiceras corniculatum* is uncommon in the Port Hedland Harbour, and is typically found in patches as a small, narrow seaward fringe on most of the creek channels. *Osbornia octodonta* trees in this area were found in the typical habitat for this species, which is at the foot of a low sandy beach overlying limestone (Semeniuk 2007). *Osbornia octodonta* and *Bruguiera exaristata* are locally rare, as both species are near the southern limit of their range, and there is an absence of suitable habitat in the harbour. Both species are well represented further north along the Western Australian coastline wherever the required habitats are present.

Further east in the study area, mangroves in the upper intertidal area are relatively sparse with *Avicennia marina* and *Ceriops australis* interspersed with samphires (predominantly *Tecticornia halocnemoides* and *Muellerolimon salicorniaceum*) (SKM 2009l). The mangroves are associated with the scattered small tidal channels that traverse the broad tidal pan.

The existing causeway and road on Finucane Island diverge near the northern bank of West Creek, creating a small pocket of mangrove habitat that is separated from adjacent habitat to the west. This infrastructure has altered the hydrological regime by restricting water flow into and out of the area to culverts such that the area, as well as that to the west of the road, remains wet for longer periods than would be expected under normal tidal ebbs and flows. These altered conditions appear to have been favourable for the growth of mangroves and for support of large populations of a diverse faunal assemblage. Large *Avicennia marina* trees are found to the east of the existing road. The fiddler crab *Uca flammula*, various mud whelks, mudskippers and the mud lobster *Thalassina anomala* were among the fauna recorded in this area (SKM 2009l, **Appendix B22**).

South Bank of West Creek

The existing causeway across West Creek is of solid construction and consequently has altered the local hydrology by completely blocking off the creek channel. Currently, the portion of the old channel adjacent to the causeway is a deposition site for fine mud and silt (particularly on the eastern side of the existing causeway).

The mangrove associations to the west of the causeway show the typical zonation pattern of mangroves in the region. The seaward edge is colonised by closed canopy *Avicennia marina* forest that is backed by a closed canopy *Rhizophora stylosa* forest. This area contains some of the largest *Rhizophora stylosa* trees (4 to 7 m high) observed during the survey (SKM 2009l). To the landward side of the *Rhizophora stylosa* band is a mixed association of *Avicennia marina* and *Rhizophora stylosa*, which then transitions to a low, closed canopy, monospecific stand of *Avicennia marina* (SKM 2009l). The benthic fauna in this area is diverse in comparison to other areas in the harbour. Mud whelks (e.g. *Telescopium telescopium* and *Terebralia palustris*), mudskippers (*Periophthalmus* sp. and *Boleophthalmus* sp.), fiddler crabs (*Uca flammula*), sesarmid crabs (e.g. *Perisesarma* sp. and *Parasesarma* sp.) and xanthid crabs (*Epixanthus dentatus*) are all found in this area, along with the arboreal snail *Littoraria filosa* (SKM 2009l).

Mangrove associations to the east of the causeway are very similar to those found on the western side. Benthic fauna is diverse and includes mud whelks (e.g. *Terebralia* spp., *Telescopium telescopium* and *Cerithidea largillierti*), the common mangrove snails (*Nerita* cf. *balteata* and *Littoraria* cf. *articulata*), oysters (*Saccostrea cucculata*), various crabs (e.g. *Uca flammula*, *Scylla* sp., *Epixanthus dentatus*, *Parasesarma* sp. and *Perisesarma* sp.) and mudskippers (*Periophthalmus* sp.) (SKM 2009l). Further into the intertidal zone is a mixed area of *Avicennia marina* and *Rhizophora stylosa* forest 2 to 5 m in height, with some open patches of mudflat. On the landward edge, some *Ceriops australis* trees are also present. Small channels in this area support populations of *Telescopium telescopium*, *Terebralia palustris*, *Cerithidea* sp., *Uca flammula* and *Onchidium damelli* (pulmonate slug) (SKM 2009l).

*Cyanobacterial Mats*

Cyanobacteria found along the north-west Western Australian coastline can occur in mats on intertidal mud flats in highly saline conditions where ponding occurs at low tide (Paling 1986). The intertidal mud flats are a region where no other vegetation occurs with the exception of two halophytic (salt tolerant)

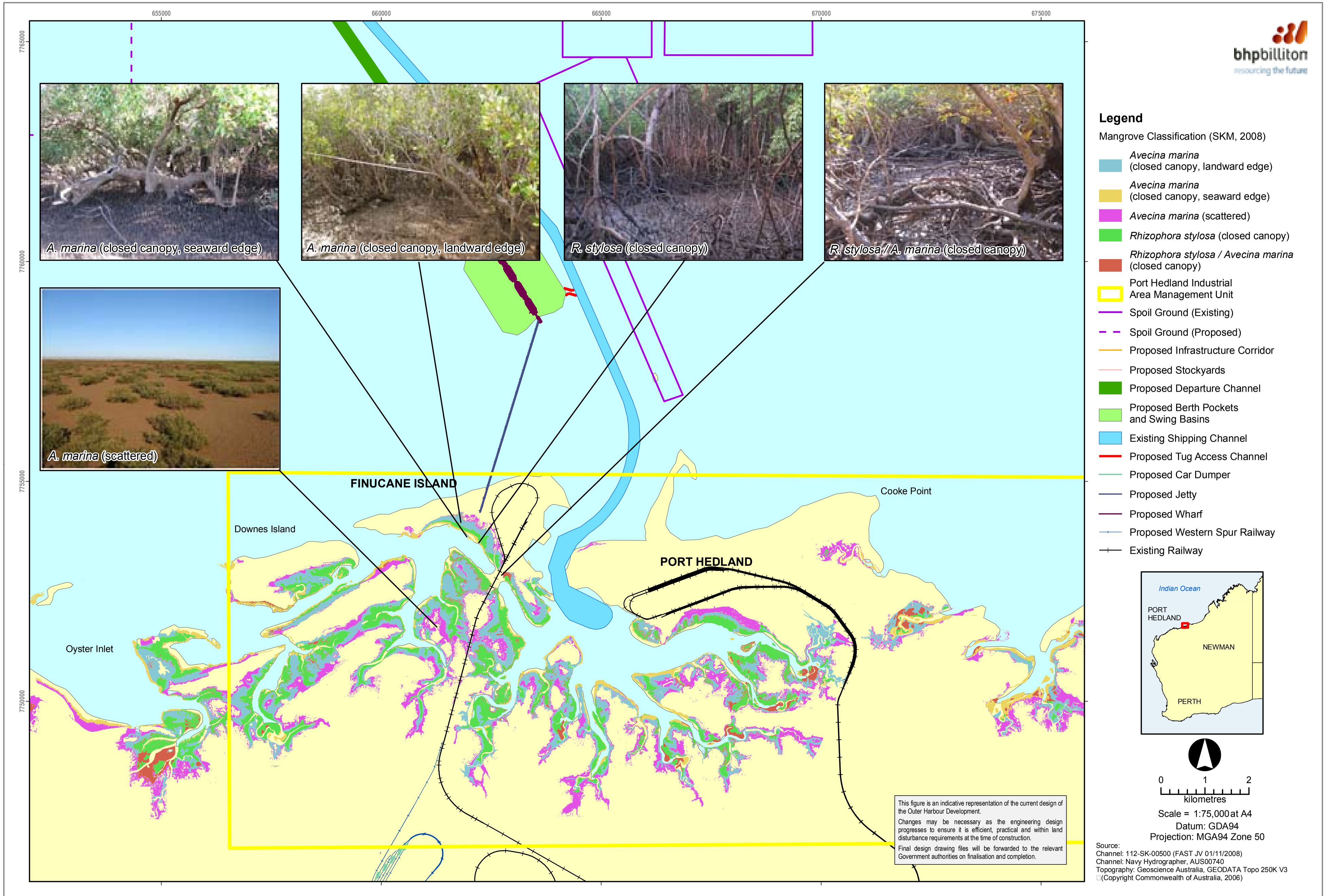



Figure 6.7 Distribution of Mangrove Vegetation Associations

samphire genera (Paling 1986). Tidal flushing in areas of mat development is restricted by a landward levee and a sill of sediment at the seaward side, which effectively creates ponding. Paling *et al*. (2003) noted that the mats may be found between the mangrove and samphire dominated zones of the upper intertidal area.

Although tolerant to high salinities and temperatures, the species diversity in cyanobacterial mats is known to decrease as soil/sediment salinity increases. In the Pilbara region, cyanobacterial mats are commonly found to have between one and three genera present. Compared to cyanobacterial mats comprising seven or more species in other regions, the lower diversity in the Pilbara is considered an indication of stress (Paling 1986). In particular, soil/sediment moisture content, salinity and temperature are considered primary environmental drivers of stress and reduced diversity in cyanobacterial mat communities. Species commonly found in these scenarios include *Microcoleus*, *Phormidium*, *Lyngbya*, *Oscillatoria* and *Aphanocapsa*, all of which are non-heterocystic[1] forms of cyanobacteria.

Diverse cyanobacterial communities are known to colonise the leaves and roots of mangroves and form extensive mats on the surrounding sediment (Paling 1986; Sundararaman *et al*. 2007). The genera *Oscillatoria*, *Phormidium* and *Microcoleus* that have been observed in the Pilbara region (Paling 1986) are widespread in these habitats. Within the disturbance envelope, there is one small area under or near the footprint of the proposed causeway where the presence of a cyanobacterial mat was confirmed during survey work undertaken to establish the monitoring sites for BHP Billiton Iron Ore's Rapid Growth Project 5 (RGP5) mangrove monitoring program (BHP Billiton Iron Ore 2008f). An area of bare tidal pan immediately north of the onshore dredged material management reclamation area for RGP5, and west of the existing conveyor causeway, includes a shallow depression of about 0.25 ha in size and this area had a cyanobacterial mat present in late January 2009.

*Salt Marshes (Samphires)*

A salt marsh is a type of marsh that is a transitional habitat between land and salty or brackish water (e.g. in bays and estuaries). It is dominated by halophytic (salt tolerant) herbaceous plants (e.g. samphires). In the Port Hedland Industrial Management Unit and surrounding areas, salt marsh habitat commonly replaces mangrove stands with increasing distance from the water line where sediments are drier and more saline (Saenger 2002). Vegetation within the supratidal is considered terrestrial (see **Section 5**).

Craig (1983) recognised four salt marsh categories:

1. wet or periodically inundated heavy clay dominated by *Tecticornia halocnemoides* ssp. *tenuis*;
2. mid to upper more sandy sites dominated by *Limonium salicorniaceum* and *Sporobolus virginicus*;
3. high well-drained sites of *Tecticornia indica*, *Frankenia ambita* and *Hemichroa dinadra*; and
4. areas of high salinity and little waterlogging characterised by *Neobassia astrocarpa*, *Trianthema turgidifolia* and some *Triodia species*.

Of these, only Category 1 is regularly inundated by monthly spring tidal cycles. The remaining categories are rarely reached by tidal water and comprise some of the vegetation on the supratidal islands, as described by Paling *et al*. (2003).

Within the area under or near the proposed causeway footprint, there are scattered samphires present on Finucane Island in a zone 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 scattered samphires are confined to one small area approximately 1 to 1.5 km to the north of the spoil management area, DMMA A as part of BHP Billiton Iron Ore's Port Hedland Finucane Island Dredging (part of RGP5).

*Offshore Intertidal Zone*

Intertidal habitats beyond the tidal creek systems and along the coastal zone of the study area, were also investigated. There were two distinct areas investigated within this zone: Finucane Platform and the Coastal Intertidal.

Finucane Platform

On the seaward side of Finucane Island is a flat rocky intertidal platform extending offshore for several hundred metres. This platform has been observed to be covered with a layer of sand with no BPPs visible. However, during some field investigations the sand cover had moved and this area was observed to support turf algae, macro algal and sparse coral habitat.

An assessment of the Finucane Island intertidal habitat during a spring low tide in February 2009

1 A heterocyst is a specialised nitrogen-fixing cell formed by some filamentous cyanobacteria, and facilitates nitrogen fixation in an oxygen-free environment. Non-heterocystic cyanobacteria do not have heterocysts and not all non-heterocystic bacteria can perform nitrogen fixation.

found three discernible zones (**Figure 6.8**; **Appendix B22**):

- Lower Intertidal Zone is characterised by prominently exposed serpulid worm casing mounds (evidenced by sand casing mounds). Mixed BPPs (mainly macroalgae and hard corals) and non-BPPs[2] including motile and non-motile invertebrates (sponges, echinoderms and molluscs) are present. A drop off (approximately 30 cm) on the seaward edge is evident however the seaward extent of any additional BPPs could not be determined due to water coverage;
- Central Zone is predominantly flat with numerous rock pool depressions. Dominant BPPs were green and brown macroalgae, including the green macroalgal genera *Caulerpa*, *Halimeda*, and *Neomeris*, and the brown macroalgal genus *Sargassum*. Living or dead hard corals are conspicuously absent from the permanently submerged rock pools. Numerous motile invertebrates are observed in the rock pools, including octopi, crabs and starfish; and
- Upper Intertidal Zone is gently sloped and marked by numerous rivulets running perpendicular to the shoreline. Typically the most landward zone, however, it is also observed close to the seaward ledge along part of the platform. This zone is more elevated than others and is likely to be exposed to air for longer durations. At the time of the survey, BPP coverage in this zone was restricted to turf algae on the flats and macroalgae in the rivulets.

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

- height on intertidal zone: diversity and density of BPPs, including hard corals and macroalgae, are observed to be inversely related to platform height (greater densities observed at lower elevations). Hard corals are restricted to the lowest elevation sections of the platform, while only turf algae and macroalgae are present on the upper intertidal sections;
- geology: rivulets are likely caused by water movement, either from rain or retreating sea water. It is within the depressions of the rivulets that macroalgae is observed, presumably due to a longer wetted duration than the surrounding flats that support turf algae; and
- sand accumulation and movement: based on field observations and archival aerial imagery, a large section of the platform appears to be inundated with sand for at least part of the year.

In addition to the zones described above, there are two large lagoons up to 1 m deep and supporting numerous *Porites* colonies (hard coral BPPs) on the eastern (Hunt Point) end of Finucane Island. The colonies reached up to 1 m in diameter and were height limited due to lack of water coverage. These colonies have previously been monitored as part of PHPA environmental monitoring program (URS 2005).

*Coastal Intertidal*

The coastal intertidal areas were assessed using digital imagery. The assessment found that the intertidal zone (defined as the area between LAT and the coastline) was dominated by tidal flats and soft bottom substrates (**Figure 6.10**). Hard substrates in the form of limestone ridges and intertidal platforms were also identified within the coastal intertidal area. Mangrove habitats found in this area are similar to that elsewhere in the Port Hedland Harbour.

### Subtidal Habitat

Provided below is an overview of the studies undertaken to define the distribution of benthic habitats in the marine study area. Further detail on the studies is provided in **Appendix B21**. In addition, a summary of the subtidal benthic habitats and the BPP communities follows.

*Investigative Studies*

Surveys conducted within the marine study area used to describe benthic habitats are summarised in **Table 6.6**. The survey effort included a total of 734 discrete observations using a number of techniques (**Figure 6.10**).

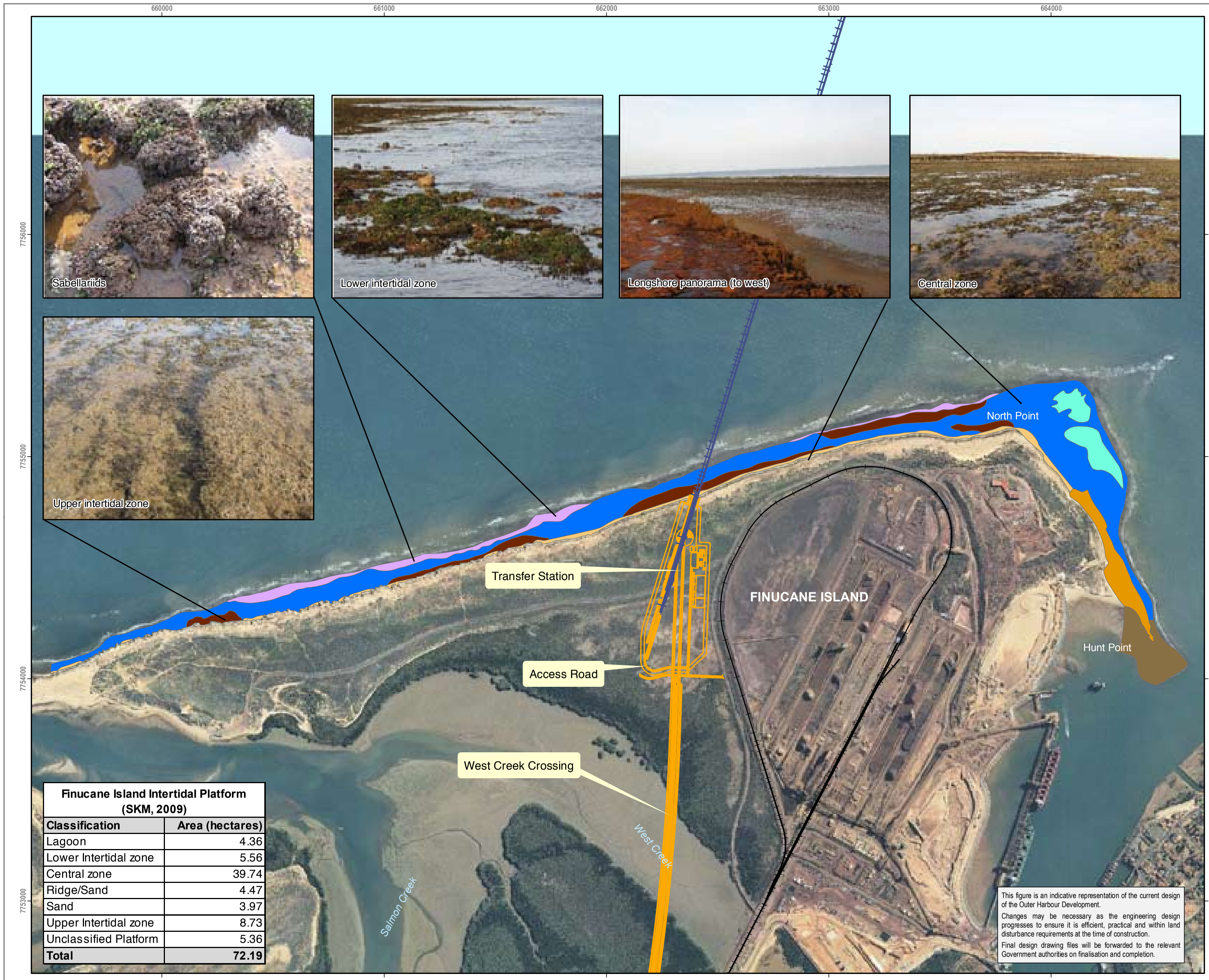
Towed Video

Surveys were conducted in winter 2007 (July), summer 2007 (December), spring 2008 (October) and autumn 2009 (May).

In July 2007, benthic video footage was captured in the nearshore environment adjacent to Finucane Island. Three transects, each of approximately 1 km in length, were filmed parallel to the coastline in depths of 0, 3 and 5 m below LAT.

The December 2007 survey which captured 42 towed video transects, ranging in length from 0.5 to 6 km,

2 In this impact assessment, non-BPPs are considered to be that component of the benthic community that is not a benthic primary producer, including sponges, soft corals, epifauna and infauna.




**Finucane Island Intertidal Platform (SKM, 2009)**

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

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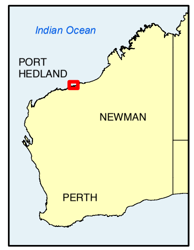
**Legend**

Finucane Island Intertidal Platform (SKM, 2009)

- Lagoon
- Lower intertidal zone
- Central zone
- Ridge/Sand
- Sand
- Upper intertidal zone
- Unclassified Platform
- Proposed Jetty
- Proposed Infrastructure Corridor
- Existing Railways




0 250 500
metres

Scale =1:16,500 at A4
Datum: GDA94
Projection: MGA94 Zone 50

Source:
Photographs: 12/02/2009 (SKM)
Orthorectified Aerial Photograph: 03/06/2010 (BHPBIO)

Figure 6.8 Intertidal Habitat on Finucane Island Platform

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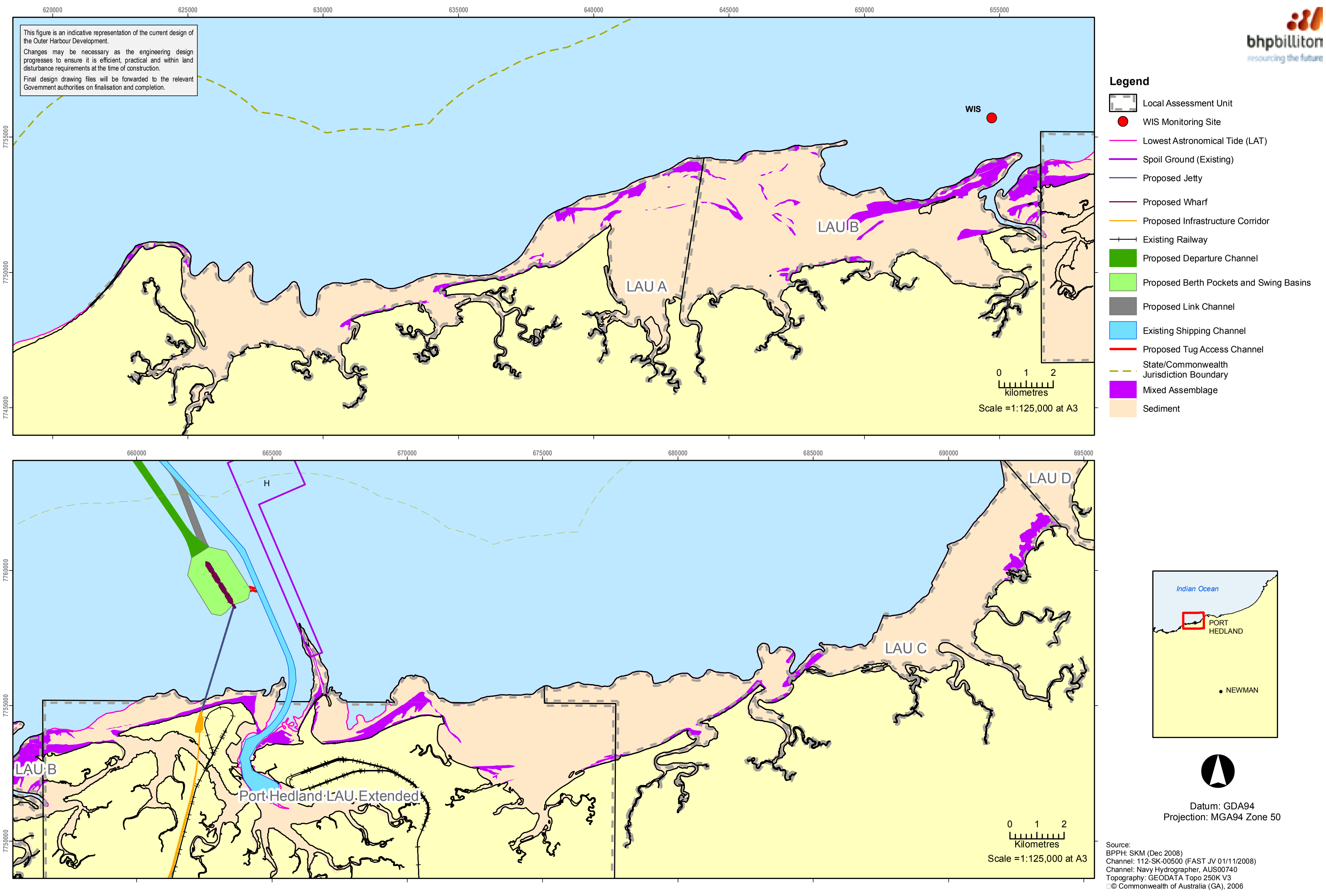


Figure 6.9 Mixed Assemblages Distribution within the Coastal Intertidal Area

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**Table 6.6 – Marine Investigations within the Marine Study Area providing Benthic Habitat Data**

| Task Description | Number of Sites/ Transects | Date/Period | Season |
|---|---|---|---|
| Towed video transects (offshore of Finucane Island) | 3 | July 2007 | Winter |
| Towed video transects (west of current dredging footprint) | 42 | December 2007 | Summer |
| Sediment sampling | 213 | December 2007 to September 2008 | Various |
| Diver video transects (throughout study area) | 52 | January to May 2008 | Summer, Autumn |
| Spot dives (aborted diver video transects) | 13 | January to May 2008 | Summer, Autumn |
| Towed video transects (throughout study area) | 21 | October 2008 | Spring |
| Towed video transects (between Weerdee and Downes Islands) | 390 | May 2009 | Autumn |
| Total | 734 | – | – |

focused on a now discounted dredging footprint and potential spoil grounds to the west of the current dredging footprint. The survey also included nearby ridgelines to identify potential hard coral habitat monitoring sites. Survey observations were used to inform habitat modelling of the area.

After completion of preliminary habitat modelling, 21 sites were visited in October 2008, for ground truthing purposes. The data points were analysed for habitat composition and density. These sites were spread throughout the study area, across a mixture of predicted topography and substrates. The sites were situated in areas with relatively low densities of field data points to test habitat model predictions and to improve confidence in the final habitat map.

In May 2009, a survey was conducted for BHP Billiton Iron Ore, Nelson Point Dredging Project, Rapid Growth Project 6 (RGP6) to the west of Port Hedland Harbour in the embayment and creek system between Weerdee and Downes Islands (SKM 2009k). A total of 390 transects of 50 m in length and spaced approximately 200 m apart, were filmed. The data were analysed for habitat composition and density.

### Diver Video Transects

From January to May 2008, 52 sites distributed throughout the study area were surveyed by divers conducting video transects. At each site, three 50 m transects totalling an area of approximately 60 m$^2$ were filmed and quantitatively analysed. Divers also recorded observations of the benthic habitat surrounding transects at each site.

Also during this period, 13 sites parallel to the coastline were visited with the intention of conducting diver video transects. As they were found to be bare sand or mud devoid of benthic habitat, video transects were not conducted but diver observations were recorded and used as inputs for habitat modelling. These sites are labelled as 'spot dives' on **Figure 6.10**.

### Opportunistic Diver Observations

For the purpose of collecting sediment samples, dives were conducted on a total of 213 sites spread across the study area from December 2007 to September 2008. Divers recorded observations of the benthic habitat at each site. The locations of the sediment sampling sites are shown in **Figure 6.10**, and are separated into each sampling period:

- during the summer of 2007-08, sediment samples were collected from 143 sites spread across the central third of the study area;
- in May 2008, sediment samples were collected from a total of 33 sites to the east and west of the proposed dredging footprint; and
- in September 2008, sediment samples were collected from 27 sites within the proposed turning basin/wharf head footprint and ten sites to the west.

1 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).

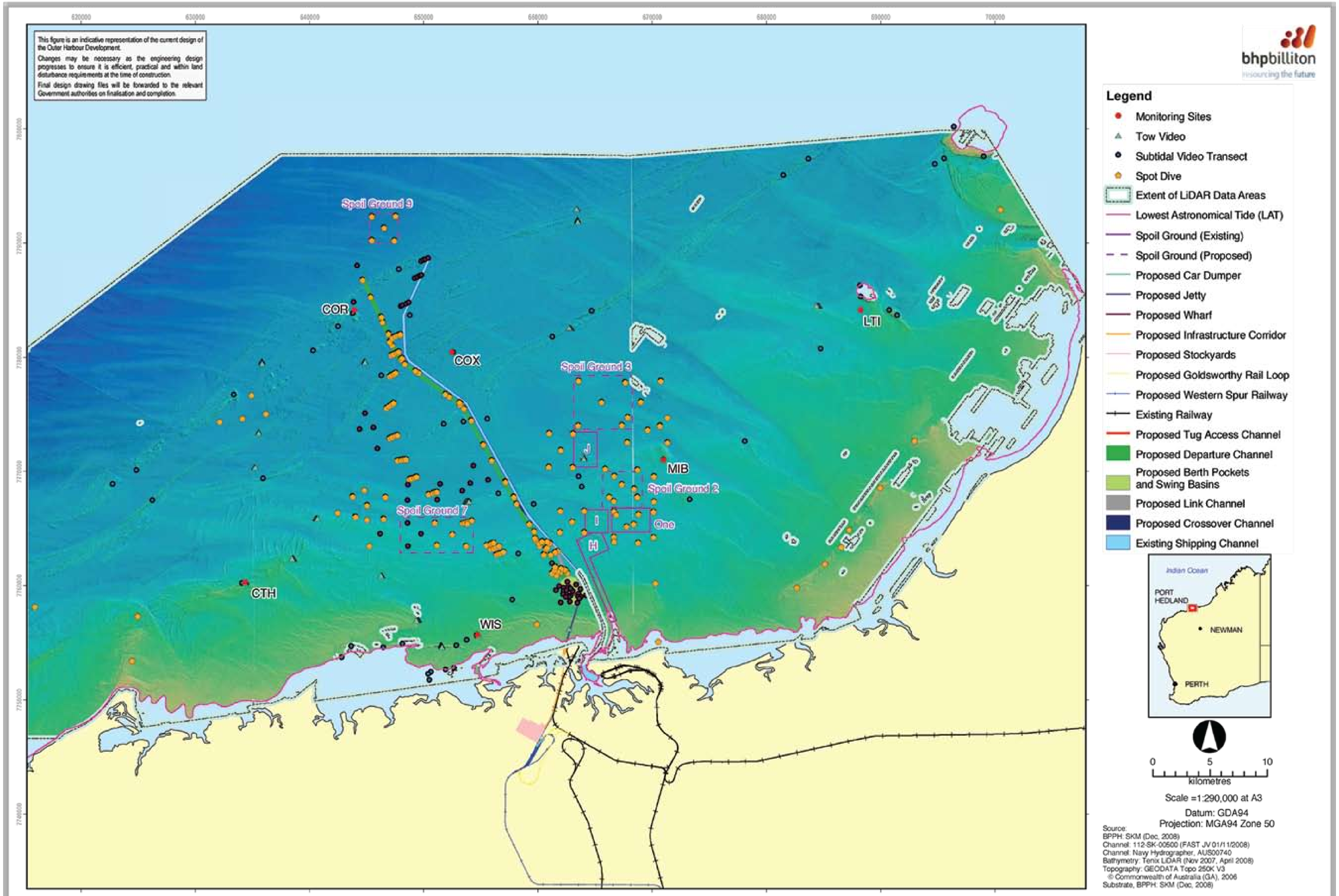


Figure 6.10 Location of Subtidal Investigations

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Subtidal Habitat Mapping

The subtidal field investigations provided qualitative and quantitative data that were subsequently analysed together with the LiDAR[1] bathymetry to generate a subtidal habitat map (SKM 2009g, 2009j). The habitat map was produced using models based on methods developed by Holmes *et al*. (2008). Modelling from LiDAR, field observations and underwater video of marine benthic habitat distribution was used to predict habitat distribution within the surveyed area. **Figure 6.11** displays the LiDAR data and regional seabed features, while **Figure 6.12** displays the corresponding habitat distribution mapped over the same area.

*Subtidal Habitats – Overview*

The clustering of features illustrated on **Figure 6.11** indicates the focus of field investigations, with a summary of findings for each feature described later in this section. The features were selected as locations for habitat surveys as they exhibited structural formations (such as islands and ridgelines) considered likely to support biota.

The modelling included two substrate types (sediment and hard substrate) and the biota that may be present on the substrate types (hard and soft corals, macroalgae, sponges and epifauna). The habitat is the combination of the substrate type and biotic assemblage. A summary of habitat cover in the study area is presented in **Table 6.7**. Estimates of the accuracy of modelled habitat distribution were made and compared against actual ground truthing sites. Final categories of 'hard substrate' and 'sediment' were predicted with high (97%) overall accuracy and the correct classification for each of the habitat categories were generated (**Appendix B21**).

The distribution of BPPs (primarily hard coral and macroalgae) is strongly correlated with areas of hard substrate and vertical relief associated with a series of offshore limestone ridges, shoals and banks as well as several islands and inshore rocky platforms that extend into the intertidal zone. Interspersed between these features are vast areas of sandy sediment and mobile sand banks with extremely sparse coverage of biota, either BPP or non-BPP. Features observed to support BPPs were surveyed in more detail by divers to provide percentage cover of the various biota. Towed video camera surveys were also conducted over the areas between the ridges to confirm they were largely bare areas which do not support BPPs.

Field investigations and habitat mapping concluded the following:

- hard substrate BPPH (both with and without BPP corals and macroalgae) comprises 7% of the study area and is mainly associated with areas on the offshore limestone ridges, shoals and rocky pavement near islands;
- the next largest BPPH area is sediment supporting BPPs, predominantly macroalgae, comprising 3.2% of the study area;
- the remaining BPPH area is sediment-covered hard substrate with BPPs including mixed macroalgae and sparse hard coral comprising 1.3% of the study area;
- intermingled among the hard coral habitat, but less prevalent, are non-BPP sponges and soft corals;
- non-BPP sponges and soft corals extend onto the plains between ridges, at decreasing densities with distance from the ridges;
- the greatest diversity and abundance of macroalgae is at Little Turtle Island; and
- the only seagrasses are patches of ephemeral species (*Halophila ovalis*) inshore of Weerdee Island, small, sparse patches offshore of Weerdee Island and in a small intertidal lagoon at the entrance to Port Hedland Inner Harbour (Hunt Point).

*Offshore Ridgeline Systems*

Several distinct ridgelines running roughly parallel to the coastline occur between 24 and 37 km offshore from Port Hedland. These form three broken lines delineating the outermost, middle and innermost ridgelines, each extending approximately 60 to 70 km in a north-east to south-westerly direction within the area captured by the LiDAR bathymetry mapping for this project (**Figure 6.11**). Reference to the Australian nautical charts series infers these ridges are part of a widespread habitat unit of offshore ridgelines extending at least as far as Bedout Island approximately 100 km to the north-east, and to Delambre Reef approximately 150 km to the south-west near Port Walcott (Australian Hydrographic Chart AUS326). Cornelisse Shoal forms part of the outermost ridgeline complex. The ridgeline varies in depth with ridge peaks ranging from 3.2 to 9 m CD and depths between the ridgelines of 15 to 18 m CD.

Benthic habitat surveyed on the outermost, middle and innermost of these offshore ridgelines was similar, comprised predominantly of non-BPPH bare sand, rock and rubble (60 to 80%). On the hard substrate BPPH, the BPPs were predominantly hard coral cover ranging from 3 to 27% and varying cover of macroalgae (0 to 14.7%). The non-BPP biota comprised mainly sponges (2.7 to 11.6%) and soft corals (0 to 3.6%).

*Inshore Shoals and Banks*

The inshore area is characterised by broken patches of less distinct ridgelines, such as Minilya Bank, and several large areas of sand banks and ridges with some hard pavement substrate.

Minilya Bank is a shallow peak with water depth 3 m CD located approximately 19 km offshore. It lies at the northern end of a low relief limestone ridgeline which extends about 10 km to the south-west with depths from 9 to 11 m CD. The benthic habitat is predominantly non-BPPH bare sand covering a hard pavement with rubble and some rock (70 to 87%) with the BPP biota of hard coral cover ranging from 3.6 to 19.6% and varying quantities of macroalgae (0 to 4.9%). The non-BPP biota comprised sponges (6.4 to 9.8%) and soft corals (0 to 6.0%).

The Weerdee ridgeline is a broken string of ridges approximately 12 km in length and 3 km offshore from Weerdee Island. This shallow system (3 to 6 m CD water depth) is predominantly sand and rubble covering a hard rocky pavement. The percentage cover of BPP biota was highly variable and predominantly hard corals (0.2 to 21.6%), while macroalgae at this site was very patchy with low coverage (0 to 8%) but a few limited areas with over 70% cover. The non-BPP biota comprised sponges (1.8 to 12.2%) and soft corals (0 to 7.1%).

The Cape Thouin area is characterised by bare sand ridges and a series of large parallel sand banks. A small area of BPPH hard substrate was located approximately 14 km from Cape Thouin and found to be predominantly bare rock platform (more than 78%) with some BPP biota comprised of hard coral (7.6%) and macroalgae (4.9%), and some non-BPP biota comprised of sponges (7.8%) and soft corals (1.1%).

*Islands*

There are several islands in the study area. Downes and Finucane Islands are separated from the mainland by tidal creeks and essentially form part of the coastal features. Weerdee Island is a small inshore island located only 1.5 km from the coast. The subtidal area of this island is very shallow (less than 2 m CD water depth) and is comprised of patchy areas of BPP biota of macroalgae (71.3%), a combination of macroalgae (30.9 to 64.7%) and sparse (less than 5%) hard corals. There was some non-BPP biota comprised entirely of small bivalve mussels.

North Turtle Island is a vegetated sandy island which is approximately 58 km from Port Hedland Harbour. The subtidal sites surveyed were predominantly sand and rubble covering a hard rocky pavement. The percentage cover of BPP biota comprised hard corals (0.2 to 18.9%) with lesser percentages of macroalgae (0 to 5.1%). The hard corals were dominated by encrusting and massive varieties. The non-BPP biota comprised sponges (0 to 8.2%) and soft corals (0 to 2.9%).

Little Turtle Island is a bare sand cay[1] almost awash at high tide, approximately 40 km from Port Hedland. The subtidal area in the vicinity of Little Turtle Island is comprised mostly of a combination of non-BPPH sand, rubble and rock (70 to 80%). The cover of BPP biota comprised hard corals (8.4 to 17.8%) and macroalgae (0 to 14.7%). The non-BPP biota was comprised of sponges (2.9 to 9.6%) and a small amount (less than 5%) of soft corals and hydroids.

*Non-Ridgeline Areas*

Between the limestone ridgelines and shoals are vast areas of non-BPPH comprised of bare, flat sandy plains and banks that cover over 85% of the study area. The nearshore area to the east of Port Hedland has a series of features that appear to be ridges on LiDAR bathymetry, however they were found to be comprised of silty sand with no cover of epibenthic biota.

The proposed Spoil Grounds 2, 3, 7 and 9 have varying degrees of sand cover (20 to 50 cm or greater depth) overlying harder substrate. None of the locations have any appreciable BPP cover. Epifauna observed are very sparsely distributed and limited to small amounts of non-BPP biota of sponges and sea whips attached to rubble, feather stars clinging to sea whips and hydroids attached to small rocks.

The dredging footprint for the proposed departure channel is mainly bare sandy substrate with no appreciable cover of benthic organisms apart from the final section of the channel that transects the outermost limestone ridge to the east of Cornelisse Shoal.

*Spoil Disposal Grounds*

Spoil Grounds 1, 2, 3, 7 and 9 are considered suitable locations for unconfined sea disposal, based on their size and depth to accommodate the planned volume of material and sailing distance from the dredging location. Should there be remaining capacity in existing Spoil Ground One, dredge spoil may be disposed at this location. Dredge spoil will be distributed amongst the proposed spoil grounds; however, the majority of the material will be placed into Spoil Grounds 3 and 7, whilst Spoil Grounds 2 and

1 A cay is a small, low-elevation island, formed of sand on the surface of coral reefs.

**Table 6.7 – Summary of Marine Habitats within the Marine Study 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 | 935 | – |
| Mangroves | 116 | – | 116 | – |
| Subtidal | | | | |
| Hard substrate | 363,442 | 898 | 5,220 | 35,531 |
| Sediment | | | 79,591 | 242,203 |
| Hard coral | 18,085 | 0.48 | 4,937 | 13,148 |
| Macroalgae | 16,026 | 162 | 3,083 | 12,781 |
| Seagrass | 86 | – | 86 | – |
| Soft coral | 3,400 | 0.33 | 733 | 2,667 |
| Sponges | 8,000 | 11.10 | 1,521 | 6,469 |
| Sessile invertebrates | 20,275 | – | 2,823 | 17,452 |

9 have been identified for purposes of contingency for management of dredge plume turbidity.

Original boundaries proposed for the spoil grounds indicated that an area in the eastern section of Spoil Ground 3 was likely to contain sensitive BPPs such as hard corals. The presence of hard corals in this area was confirmed during ongoing marine investigations. Consequently, Spoil Ground 3 was reduced in size, thereby avoiding direct impacts to this sensitive habitat. All Spoil Grounds are located in areas of predominantly sand between limestone ridgeline features (**Figure 6.13**).

Further detail on the spoil grounds and spoil ground selection process is included in **Appendix B20**.

### Subtidal Benthic Primary Producers

*Macroalgae*

Macroalgae, or seaweeds, are marine plants that rely on light for photosynthesis and grow almost exclusively in shallow coastal waters where they receive sufficient light. They are simpler than land plants because they do not have true roots, flowers or vascular tissue and absorb their nutrients directly from the seawater. Macroalgae are classified into three groups, largely based on their colour: red (Rhodophyta), brown (Phaeophyta) and green (Chlorophyta) (Huisman *et al*. 2006).

Surveys undertaken at Dampier by Huisman and Borowitzka (2003) found 201 species of macroalgae in nearshore areas, commonly on shallow limestone pavements. The most abundant macroalgae found during the surveys were brown algae (Phaeophyta), including species from the genera *Sargassum*, *Dictyopteris* and *Padina*. As well, species from the group of green algae (Chlorophyta) were common: *Caulerpa* and the calcareous *Halimeda*. Representation of red algae (Rhodophyta) included corallines (e.g. *Amphiroa* and *Galaxaura*) and algal turf.

Surveys of the three outermost limestone ridgelines undertaken for the Outer Harbour Development recorded cover of macroalgae varying between 0 and 15% (mostly less than 5%) (SKM 2009g). Three sites in the dredging footprint had no macroalgae present at the time of the survey. However, in some areas macroalgae was locally abundant and dominant. At Weerdee Ridge, 11 km west of the Port Hedland Harbour entrance, macroalgal cover varied between 0 and 71% of the substrate. *Caulerpa* and *Halimeda* spp. were the most common algae at this site (SKM 2009g).

The shallow subtidal limestone pavement at Weerdee Island has approximately 30 to 40% cover of macroalgae, and common genera include *Caulerpa*,

* 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**.

*Halimeda* and *Sargassum* (SKM 2009k). At Little Turtle Island, macroalgal cover on subtidal pavement was less and ranged from 0 to 15% (generally less than 5%). The intertidal pavement of the island had similarly sparse algal cover although species diversity was higher. Thirty-six species of algae were recorded, and comprised 18 red, 13 green and five brown algal species (refer **Appendix B22**). Similar diversity and community structure were observed further afield at North Turtle Island although there were some differences in the species present. Subtidal pavement around North Turtle Island did not support any macroalgae (SKM 2009k). A recent survey of the intertidal platform on the seaward side of Finucane Island, on the western side of the entrance to Port Hedland Harbour, found small but dense patches of macroalgae, predominantly *Caulerpa* and *Sargassum* spp. A selection of representative photographs is displayed in **Figure 6.14**.

The presence and abundance of macroalgae commonly varies substantially between seasons in tropical waters as they are strongly driven by environmental factors such as water clarity, nutrient availability and sand movement (Huisman & Borowitzka 2004). *Sargassum* spp. is a brown alga that is one of the most prolific macroalgae present (in terms of biomass) in the Pilbara region (Huisman 2004) and has strong seasonal growth patterns. Several species of *Sargassum* were recorded during field surveys in the marine study area. These plants exhibit a pattern of annual growth and reproduction followed by senescence[1]. Individual plants attain lengths of 3 m by late summer before breaking off above the holdfast in early winter. The detached *Sargassum* fronds form large floating rafts, some of which drift ashore while others are carried offshore by tidal and wind-driven surface currents. These algae are known to occur on the shoals offshore from Port Hedland and have been observed at four of the six sites chosen for ongoing coral health and water quality monitoring (refer to the section below on hard corals).

*Seagrasses*

Seagrasses are flowering plants that live in shallow coastal waters in most parts of the world. They occur in intertidal and subtidal marine and estuarine environments. In Australia, seagrasses are found in tropical and temperate waters. Of the 60 species found worldwide, approximately 30 occur in Australia.

Species typical to coastal environments of the Pilbara (Huisman 2004, 2008; Huisman & Borowitzka 2004) include:

- *Cymodocea angustata;*
- *Enhalus acoroides;*
- *Halophila decipiens;*
- *Halophila minor;*
- *Halophila ovalis;*
- *Halophila spinulosa;*
- *Halodule uninervis;*
- *Thalassia hemprichii;* and
- *Syringodium isoetifolium.*

Walker and Prince (1987) recorded four seagrass species in marine areas adjacent to Port Hedland, namely *Thalassia hemprichii*, *Halodule uninervis*, *Halophila ovalis* and *Halophila decipiens*. *Halophila decipiens* can be distinguished from other species of the genus by its leaf margin which has very fine serrations, and is generally much smaller than *Halophila ovalis*.

*Halophila ovalis* has a tropical distribution and often forms extensive beds which are an important food source for dugongs (Edgar 1997). *Halophila ovalis* and *Halodule uninervis* are generally considered to be pioneer or opportunistic species capable of rapidly colonising new areas, particularly after disturbance, and surviving well in unstable or depositional environments (Waycott *et al.* 2007; Lee Long *et al.*1993; Bridges *et al.* 1981; Birch & Birch 1984). These species are also found in ephemeral and dynamic communities and are therefore better adapted to recovery after disturbance than other later successional species of seagrass (Waycott *et al.* 2007).

Field investigations by SKM reported sporadic observations of the four seagrass species listed above (SKM 2009c) (**Figure 6.15**). A sparsely inhabited (approximately 5 m x 5 m) area of *Halophila decipiens* (**Figure 6.15**) was observed offshore of Weerdee Island. A similarly small and sparse stand of *Halophila ovalis* was observed at North Turtle Island. In addition, drop video investigations identified patches of seagrass, predominantly *Halophila ovalis*, in the shallow protected embayment between Weerdee and Downes Islands, to the west of Finucane Island (SKM 2009d). 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, and were mixed assemblages most commonly present with macroalgae and occasionally sponges.

1 Senescence in *Sargassum* is when the plant sheds its foliage annually, reducing it to a rudimentary basal plant from which the plant grows again the following season.

Given the field effort undertaken (refer **Table 6.6**) and the temporal breadth of these studies, it is likely that the distribution of seagrass, specifically *Halophila* spp., throughout the Port Hedland region is spatially and temporally dynamic. In addition, it appears that seagrasses in the study area are preferentially located in areas that offer shelter from prevailing metocean conditions (e.g. in the lee of islands).

*Hard Corals*

Hard corals (*Scleractinia*) occur primarily in tropical areas and mostly rely on light to grow. Most hard corals acquire a significant portion of their energy from symbiotic microalgae that live in the coral polyps. They are generally attached to the seabed and sequester carbon from the surrounding seawater or air and convert it to organic compounds through photosynthesis. Hard corals are considered to be the most sensitive marine receptors to increases in turbidity and sedimentation (Brown *et al*. 1990).

The distribution of hard corals within the marine study area was determined from the marine habitat survey at 52 sites. The field survey results show that percentage cover of hard corals on the hard substrate sites ranged from less than 3 to 27% (coral cover) and the majority of the substrate at all sites was the bare substrate component (sand, rubble and rock) (**Table 6.8**). Non-reef areas including the potential spoil grounds were primarily sandy sediment with no observed coral. The outer ridgeline systems generally have higher coral cover than the islands or the inner ridgeline or shoal system.

The species richness of coral taxa at all sites surveyed in the study area was very low in comparison to other studies carried out in the Pilbara region and no corals considered endangered or unique to the region have been identified.

A total of 51 species of coral from 19 genera were identified from areas offshore from Port Hedland, which is considerably lower than the 120 coral species from 43 genera recorded in the Dampier Port and inner Mermaid Sound, Dampier (Blakeway & Radford 2005). The estimate for the offshore Port Hedland region is based on a smaller sampling effort when compared with the Mermaid Sound region. Although more species may be present offshore from Port Hedland, the number of coral genera recorded during field surveys is considered to be representative of the actual number of coral genera present in these coral communities.

Based on the generally low species richness and abundance of corals and the dominance of corals of the genus *Turbinaria*, coral communities that inhabit subtidal habitats in the Port Hedland region can be described as predominantly high turbidity (low light), high sedimentation adapted communities (SKM 2009r).

Coral monitoring transects were established at the water quality monitoring sites described in **Section 6.4**. The sites were considered to be representative of the limestone ridgelines and shoals in the region. Cornelisse and Coxon Shoals are the most prominent features on the offshore ridgelines (**Figure 6.16**). Hard coral colonies at these locations were sparse and mainly located along the slope at depths between 9 to 12 m CD. The hard coral genus *Turbinaria* dominated; however, colonies of *Acropora* spp. were also common at the furthest offshore ridge, Cornelisse Shoal.

The midshore shoals and islands of the study area are represented by Little Turtle Island, Cape Thouin and Minilya Bank (**Figure 6.16**). The habitat at Little Turtle Island is primarily flat, rising from a depth of 9 to 7 m CD. The substrate consists of sand and rubble with occasional corals sparsely distributed and dominated by *Turbinaria* spp. Cape Thouin (**Figure 6.16**) has an extensive rocky platform at a depth of 6 m CD and the extensive coral community was dominated by *Turbinaria* spp. and *Porites* spp. Minilya Bank, a low mound rising from a depth of 11 to 9.5 m CD was also dominated by sparse colonies of *Turbinaria* spp.

The inshore ridgeline to the north of Weerdee Island is situated in shallow depths (5 m CD) and the coral community was sparse and dominated by *Turbinaria* spp. and low encrusting *Porites* spp.

In general, the ridgelines, islands and shoals in the study area were dominated by *Turbinaria* spp. colonies with diameters up to 0.5 m. The small colony sizes indicate either slow growth rates, possibly as a result of local environmental conditions, and/or high colony turnover rates due to seasonal cyclonic activity and coral bleaching caused by elevated water temperatures. Evidence of grazing on live hard coral tissue by the gastropod *Drupella* spp. was observed at one hard coral colony (*Turbinaria* spp.) at Coxon Shoal. Similarly the coral disease, Black Band Disease (BBD) was observed on one coral colony (*Turbinaria* spp.) at Cornelisse Shoal. The prevalence and intensity of these natural pressures on coral species is difficult to estimate, but the relatively few records of either predators like *Drupella* spp. or diseases like BBD observed during the baseline program suggest that these were not significant pressures on the coral communities over that time period.

In the summer months when sea temperatures are elevated, the prevalence and severity of coral diseases, such as BBD, may increase (Willis *et al*. 2004). Similarly, the corallivore *Drupella* spp. can systematically damage large areas of coral communities when in high numbers (Turner 1994).

Synchronous spawning or 'mass spawning' of coral colonies was first reported on the Great Barrier Reef (Babcock *et al.* 1986). 'Mass spawning' in corals is the ejection of reproductive propagules (larvae, eggs or sperm) by a large number of coral species on consecutive nights during one period of the year.

Previous studies of coral spawning on inshore regions on the north western coastline of Western Australia identified the mass spawning period to occur six to eight days after the full moon in the autumn months of March and April (Stoddart & Gilmour 2005; Baird *et al.* 2010). Recent research suggests that additional spawning for *Acropora* spp. may occur on reefs in Northern Western Australia during spring (Rosser & Gilmour 2008).

Extensive surveys of the benthic habitat offshore of Port Hedland were undertaken between December 2007 and May 2008 (SKM 2009g) to determine the extent and timing of coral spawning in the Port Hedland region. Of the hard corals present in the study area, species from the genera *Turbinaria* were the most dominant.

In addition, to accurately predict the time of spawning of the dominant and sub-dominant coral species, a small piece of coral from each species was collected and processed at a laboratory for histological analysis. This approach allowed the exact stage of egg and sperm development of corals to be determined.

Six coral spawning surveys have been conducted over 2009 and 2010, three in spring and three in autumn, at six locations. Results from the surveys found:

- autumn spawning surveys indicated that no real period could be defined as a 'mass spawning' of *Turbinaria* colonies and it appears that *Turbinaria* colonies are expelling gametes over an extended period from December to April with the main spawning period occurring in autumn;
- *Favites pentagona* appears to spawn primarily in the autumn months. There was some evidence of spawning outside of this period by a quarter of the individuals examined, and this proportion of individuals may have spawned in the spring months given that some gametes were found in some colonies during spring;
- *Acropora spp* appear to spawn mostly in early spring after the October full moon. There is some evidence of additional spawning after this full moon by less than 10% of individuals; and
- the spawning of *Montipora* appears to occur mostly in late spring after the December full moon. There is some evidence of additional spawning in the autumn months by less than 20% of individuals sampled.

### 6.2.1 Non-Benthic Primary Producers

In this impact assessment, non-BPPs are considered to be that component of the benthic community that is not a BPP, including sponges, soft corals, epifauna and infauna. See **Section 10** for the full definitions of impact assessment guidance.

#### Sponges and Soft Corals

Sponges are simple, multi-cellular animals which permanently attach themselves to substrate and can be found in a range of locations from shallow tidal waters to the deep ocean. Sponges are predominantly filter feeders that mostly consume food particles and bacteria in the water column and occasionally prey on small crustaceans when the abundance of particulate material in the water column is poor (Pile *et al*. 2003; Yahel *et al*. 2003, 2007). Some sponges have a symbiotic relationship with green algae, dinoflagellates or cyanobacteria from which they derive nutrients.

Unlike hard corals, soft corals (octocorals) do not produce a calcium carbonate skeleton and are not colony-forming, although they are typically found in reef environments. They are simple multi-cellular animals with a polyp structure. Most live in nutrient rich waters with reduced light intensity. A few species of soft corals also support photosynthesising symbiotic algae. Sponges and soft corals are not recognised as BPPs under the EPA Guidance Statement No. 29 (EPA 2004c) because the great majority of species and genera do not support symbiotic algae.

In the study area, sponges and soft corals are found along the outer and inner ridgeline systems and the island shoals. They commonly co-habit the ridgelines where hard corals are found. Unlike hard corals, soft corals and sponges also extend onto a narrow margin of the inter-ridge flats. The proposed spoil ground locations are predominantly bare with the exception of some sparsely distributed individuals of soft corals and sponges (**Table 6.9**) (SKM 2009k).

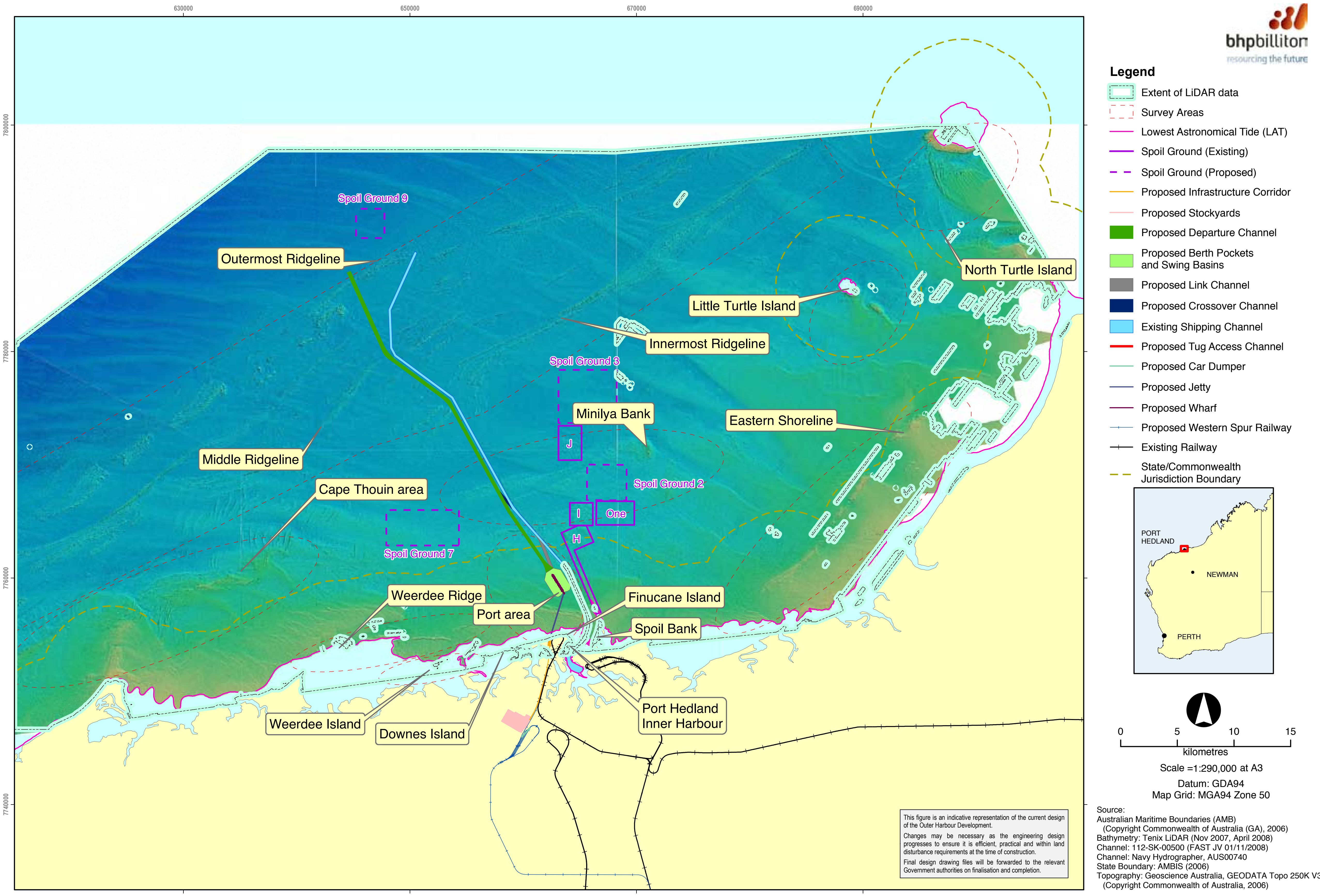


Figure 6.11 Regional Subtidal Features and Survey Areas

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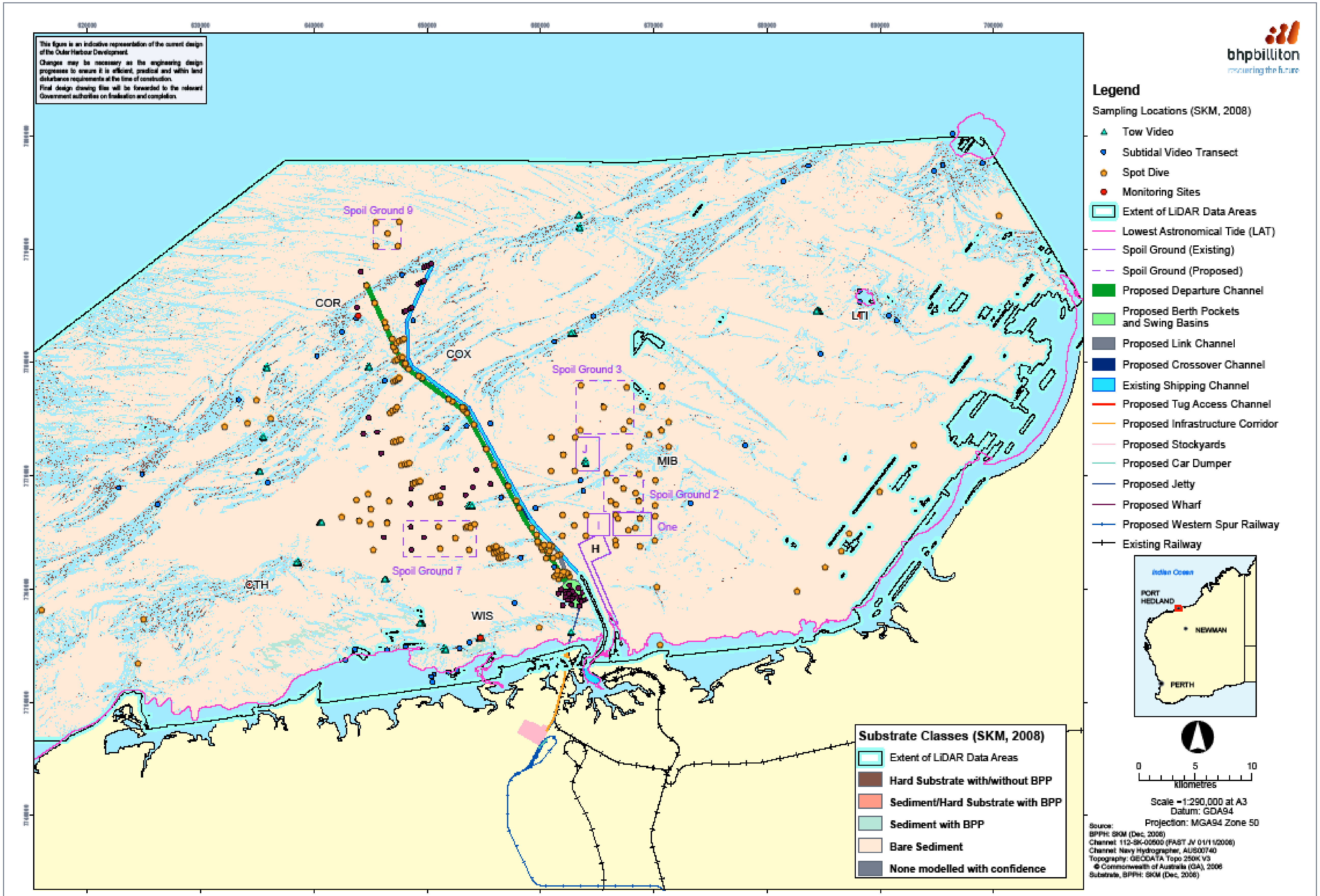

Figure 6.12 Subtidal Habitat Map of Study Area

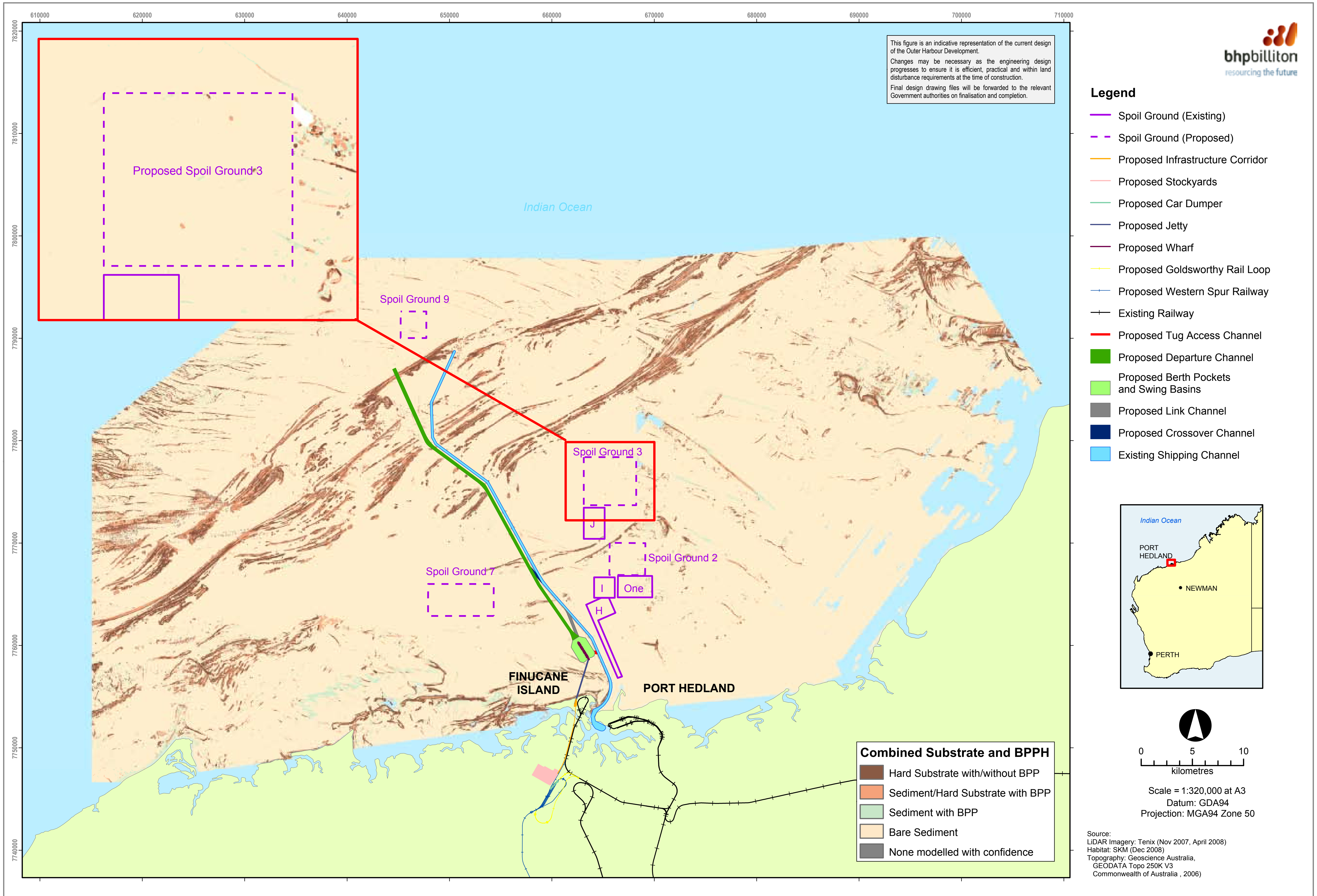


Figure 6.13 Habitat map illustrating the reduction in spoil ground 3 to exclude sensitive habitat, June 2009

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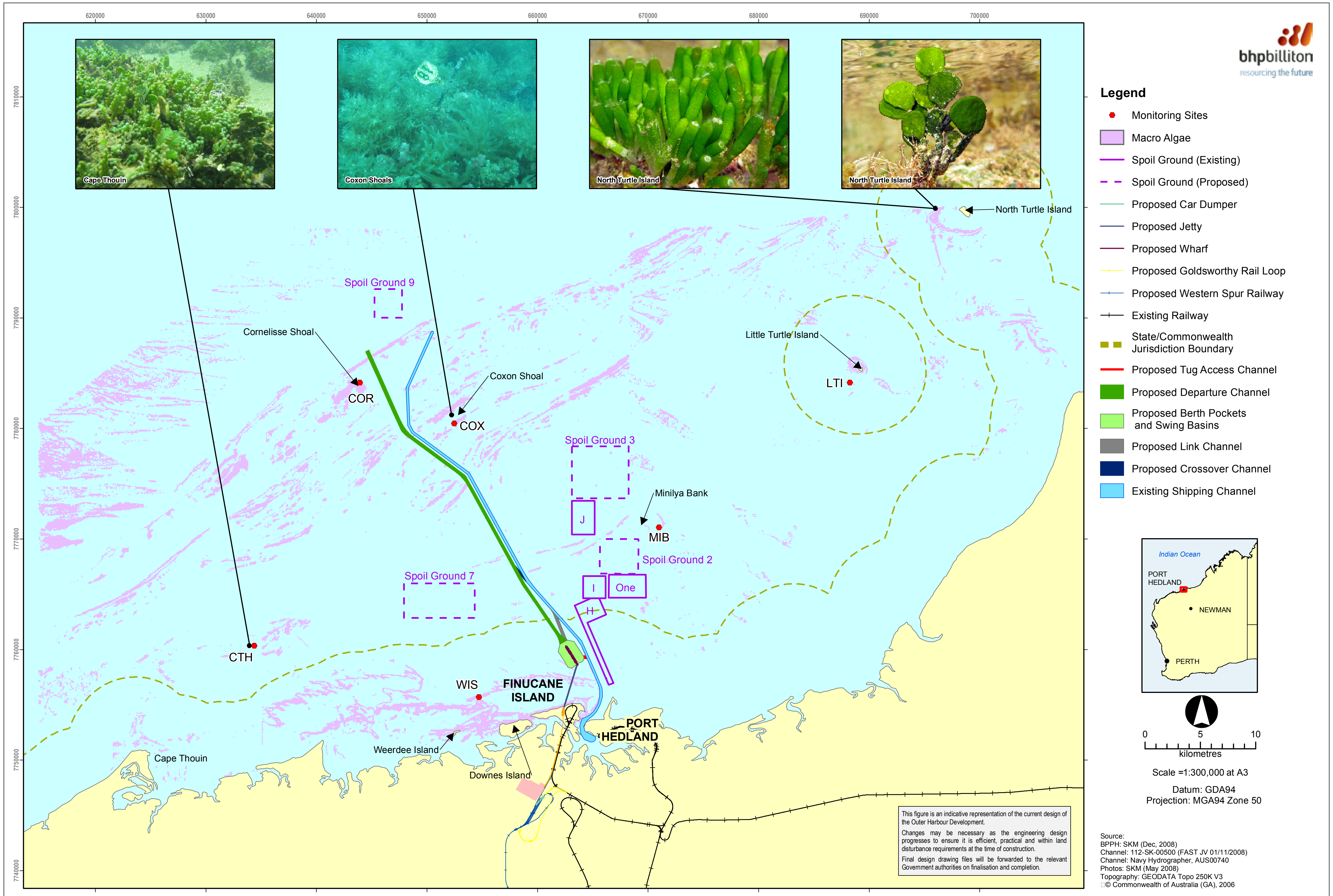


Figure 6.14 Macroalgal Distribution in the Study Area

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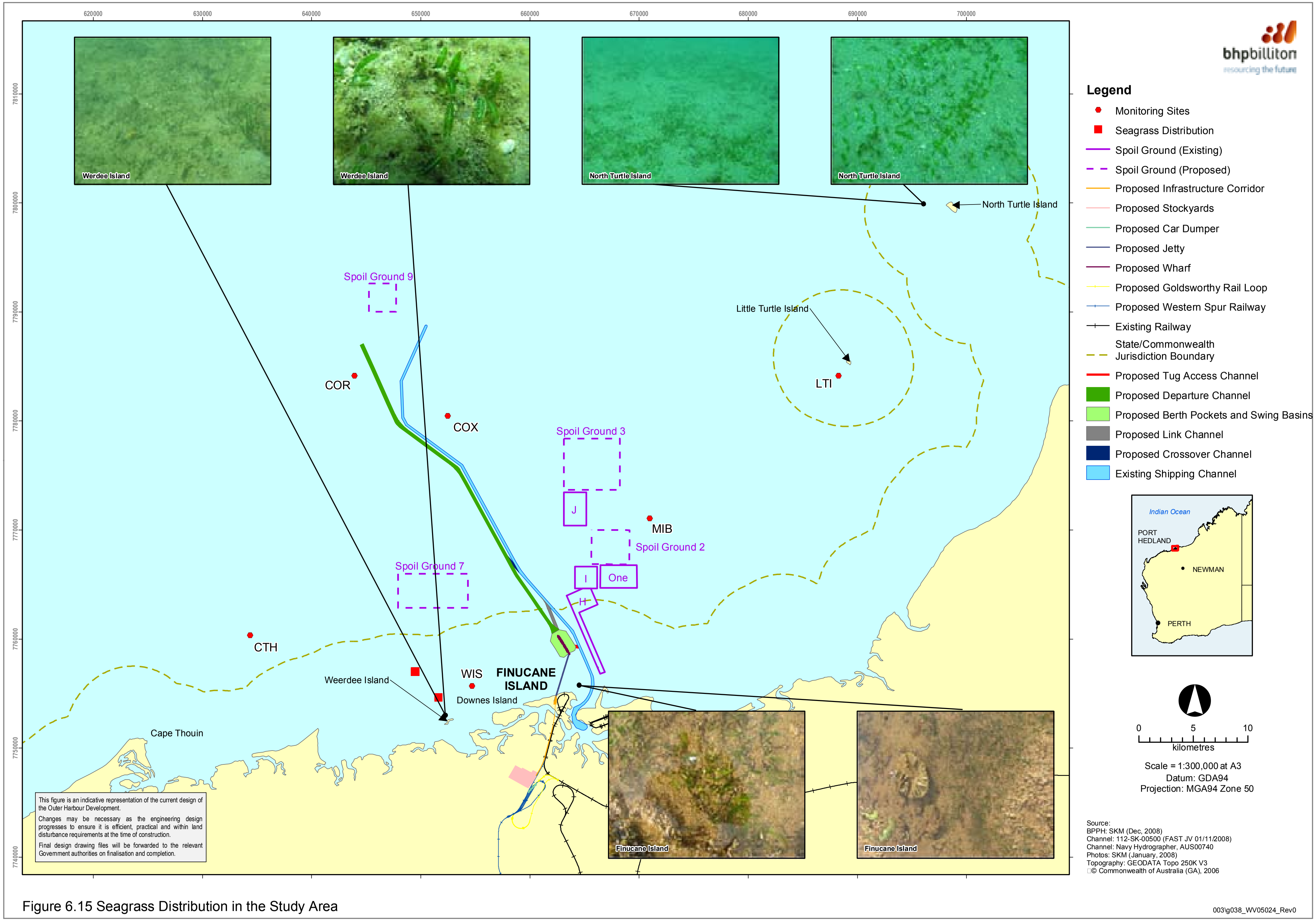


Figure 6.15 Seagrass Distribution in the Study Area

**Table 6.8 – Hard Coral Cover as Recorded by Field Observations in Marine Study Area**

| Area | | Proximity to Port Hedland entrance | Hard Coral Cover (%) | Bare Component (%) |
|---|---|---|---|---|
| Outer Ridgeline Systems | Outermost Ridgeline | 37 km NW | 4.9–27.1 | >60 |
| | Middle Ridgeline | 31 km NW | 5.8–21.8 | >69 |
| | Innermost Ridgeline | 24 km NW | 3.3–22.9 | >67 |
| Inner Ridge/Shoal Systems | Minilya Bank | 19 km NE | 3.6–19.6 | >67 |
| | Proposed Port Areas | 4–6 km N | 0.0–12.9 | >79 |
| | Weerdee Ridge | 11 km W | 0.2–21.6 | 11–75 |
| | Cape Thouin Area | 40 km W | 7.6 | >78 |
| Islands | Weerdee Island | 12 km W | <5 | 12–66 |
| | North Turtle Island | 58 km NE | 0.2–18.9 | >81 |
| | Little Turtle Island | 40 km NE | 8.4–17.8 | >69 |
| Sand Plains | Eastern Shoreline | Inshore, from Port Hedland to Spit Point | 0 | 100 |
| | Potential Spoil Ground Locations[1] | Refer to **Figure 6.16** | 0 | 100* |
| | Proposed Channel Footprint[2] | Refer to **Figure 6.16** | 0 | 100** |

Source: Summarised from SKM (2009k) (surveyed December 2007 to May 2008)
1 a series of potential spoil ground locations investigated for the proposed Outer Harbour Development
2 sites sampled at a proposed footprint which was subsequently realigned. Further investigations conducted within the current dredge footprint concluded the same results
* with the exception of sparse coverage of epifauna
** with the exception of the final section of the channel which intersects the outermost ridgeline (refer to table above for composition of hard coral and bare environment to overall benthic environment of the outermost ridgeline)

## Epifauna

Epifauna are benthic animals that live on the surface of the seabed, either attached to it (sessile) or freely moving about (mobile). Hard corals, soft corals and sponges have been described within **Section 6.6.2**, and this section describes the remainder of the epifaunal community observed within the study area. Opportunistic epifaunal observations were made by divers while conducting supporting environmental investigations such as habitat ground truthing, sediment sampling and coral health monitoring.

The soft sediments of the study area have a characteristic epifaunal community dominated by echinoderms such as sea stars, urchins and sea cucumbers, many of which bury themselves during the day. Many of the sea star species are opportunistic feeders and prey on molluscs or alternatively they will scavenge. The majority of the sea cucumbers observed in the area were detritivores[1], however there were several sea apples (*Pseudocolochirus violaceus*) which filter-feed. The soft sediments in the study area occasionally have small rocky outcrops or low relief bommies. These hard substrates provide suitable surfaces for the attachment of sessile invertebrates such as ascidians, bryozoans and hydroids that would not otherwise inhabit the area. As well, mobile epifauna such as feather stars (crinoids) use these structures to raise them above the sediment to filter feed.

One habitat observed from aerial photography appeared to be a macroalgal bed but habitat ground truthing investigations revealed a bed of mussels, *Brachidontes* cf. *ustulatus* (SKM 2009j). These small mussels are common in the north-west region, often forming large beds, and are preyed upon by organisms such as sea stars (several of which were observed in the area) and octopus.

Unlike soft sediment areas, hard substrates such as reef areas and pavement, provide permanent attachment points for sessile epifauna as well as perches and hiding places for mobile epifauna. The abundance and diversity of epifauna observed in these habitats markedly exceeds that found in the soft sediment areas where many of the mobile species are hidden beneath the sediment. The most conspicuous were the hydroids, feather stars (crinoids), sea cucumbers and ascidians. Many of the mobile epifaunal species are cryptic, such as rock lobster, crabs and gastropod molluscs, and were less commonly observed by divers during the survey.

None of the species observed are listed as endangered or are restricted in their distribution. The species observed are all common tropical species found throughout the north-west of Australia and further afield.

1 Detritivores are organisms that feed on and break down dead plant or animal matter.

**Infauna**

Infauna are animals that live within the sediments of aquatic environments. Typically, marine infauna are dominated by polychaete worms, molluscs and crustaceans. Conditions within the sediments, including the supply of water, oxygen and nutrients to the sediment and the stability of the system, affect the type and abundance of infauna in any particular environment (Little 2000).

HGM (1997) identified a total of 183 infauna species in the Port Hedland Inner Harbour, of which approximately 55% were polychaete worms, 24% molluscs and 18% crustaceans. A study conducted in 2003 showed that the offshore sediment environment at Cape Lambert (to the south-west of Port Hedland) was dominated by arthropods, annelids and molluscs and varying numbers of echinoderms, cnidarians, nematodes, nemerteans, bryozoans and chordates (SKM 2003a). The species richness and abundance was less than that of the Inner Harbour at Port Hedland.

A benthic infauna survey (SKM 2010) was conducted at Spoil Ground One for BHP Billiton Iron Ore's, RGP6 project in accordance with Section 4.4.2 of the NAGD (Commonwealth Australia 2009) to monitor change at the spoil ground and the containment of effects within the spoil ground boundary for BHP Billiton Iron Ore's RGP6 (BHP Billiton Iron Ore 2009d). The purpose of this survey was to determine the baseline composition of the benthic infauna at Spoil Ground One and to confirm the appropriate number of replicates and adequate spatial distribution of sampling locations required for subsequent surveys.

The survey involved the collection of sediment samples within and adjacent to Spoil Ground One using a Van Veen grab. Infauna found within the samples remaining on a 1 mm sieve were identified to species level. A selection of samples were analysed for particle size distribution (PSD) and total organic content (TOC) to determine whether these abiotic parameters could be used to make predictions on infauna community change. PSD and TOC content will also be tested and their relationship to infauna composition re-examined, following the completion of the sea dumping program. This is because the dredged spoil will be predominantly silty material and will likely change the sediment characteristics in and around the spoil ground after dredge spoil disposal.

The results of the baseline survey (SKM 2010) are summarised as follows:

- a total of 1,035 species were collected, comprised of 39,036 organisms;
- the most species rich phyla were Annelida (300 species collected), Crustacea (266 species) and Mollusca (224 species), while the most abundant phyla were Crustacea (15,457 individuals) and Annelida (14,964 individuals). The faunal groups were typical of lower latitude soft bottom benthic environments;
- Spoil Ground One and the adjacent eastern area had relatively similar species richness and abundances. Both areas had significantly greater species richness and abundance compared to the reference area;
- statistical analysis demonstrated that the abiotic parameters measured were variable across the sampling stations. Samples collected in the spoil ground area were relatively coarser compared to the four locations furthest from Spoil Ground One, which was established as the reference area; and
- there was a decrease of the species richness and abundance from west to east.

### 6.6.4 Avifauna (Seabirds and Shorebirds)

This section considers birds utilising habitat in the marine and intertidal areas of the proposed Outer Harbour Development. Avifauna that are considered relevant to the terrestrial component of this project are discussed in **Section 5**. Mangrove passerines (songbirds) are discussed in **Section 6.6.2**. The impact assessment is discussed in **Section 10.6**.

**Seabirds**

The Seabirds considered here include some eagles and kites, frigates, some shearwaters, gulls, terns, and boobies. These birds typically dive for prey from the air, and usually are associated with shallow coastal seas with many hunting in groups for shoals of fish, crustaceans and cephalopods. They include both locally resident and migratory species.

The intertidal areas along the tidal channels of the Inner Harbour and the tidal flats of the shoreline along the coast all provide suitable foraging habitat for seabirds. Seabirds also utilise the shallow tidal channels and embayments along the coastline and the shallow coastal waters.

A total of sixteen seabird species were determined to have the potential to utilise habitat within the study area (ENV 2009e, 2009f). Summer and winter terrestrial fauna surveys of the terrestrial study area (ENV 2009e, 2009f) included a habitat assessment and opportunistic sightings for these species. Fourteen seabird species were recorded during these surveys, including three which are listed as migratory under the EPBC Act (see **Section 6.6.5**).

While the waters surrounding the Outer Harbour Development provide feeding grounds for these migratory seabirds, they were only observed in relatively small numbers in and around the terrestrial disturbance envelope and marine infrastructure footprint either flying over or foraging. No suitable nesting areas were identified. This indicates that the disturbance envelope and marine infrastructure footprint does not represent important habitat for these species.

Further offshore, Bedout Island, approximately 100 km north-east of Port Hedland Harbour, serves as a rookery for some species of seabirds and supports one of the largest colonies of Brown Boobies (*Sula leucogaster*) in Western Australia (DEWHA 2008). Masked Boobies (*Sula dactylatra*), Lesser Frigatebirds (*Fregata ariel*), Roseate Terns (*Sterna dougallii*) and Common Noddies (*Anous stolidus*) also breed in the area. The Island lies outside the marine study area.

**Shorebirds**

Shorebirds referred to in this section include oystercatchers, some sandpipers, stilts, herons and bitterns, ibises and spoonbills, and plovers. These are birds that typically forage on exposed tidal flats at low tide and many have adaptations (bills, long legs) to enable them to hunt for specific prey items in, and on, the mud and sand, or on exposed reef. A number of these shorebird species are migratory and have entered Australia from Asia or the Arctic Circle. These species are listed as migratory under the EPBC Act.

Summer and winter fauna surveys of the terrestrial study area (ENV 2009e, 2009f) included a habitat assessment and opportunistic sightings for shorebird species. Shorebirds were found to utilise the dunal, mangrove and tidal flat habitat areas on and around Finucane Island for foraging and roosting. During low tide, these species dispersed throughout the tidal mudflats of the study area to roost and forage. At high tide they would converge and roost at one location at the far south-western tip of Finucane Island.

A total of 45 shorebird species were determined to have the potential to utilise habitat within the study area (ENV 2009e, 2009f). Of these, 26 species were recorded during the summer and winter terrestrial fauna surveys (ENV 2009e, 2009f).

Eighteen of the shorebird species identified during surveys are listed as migratory under the EPBC Act. EPBC Act Policy Statement 3.21 outlines the criteria used in determining the importance of an area for many of these species. According to these guidelines, an area that supports an ecologically significant proportion of a population (generally defined as 0.1% of the flyway population of a species), or at least 2000 shorebird individuals, or at least 15 different shorebird species, is considered important habitat. The field surveys did not identify ecologically significant numbers of any of the migratory shorebird species at Finucane Island (ENV 2009e, 2009f).

Supplementary data on shorebird numbers is also available through the Birds Australia national shorebird database. This database identifies the Banded Stilt (*Cladorhyncus leucocephalus*), Bar-tailed Godwit (*Limosa lapponica*), Broad-billed Sandpiper (*Limicola falcinellus*), Curlew Sandpiper (*Calidris ferruginea*), Great Knot (*Calidris tenuirostris*) and Red-necked Stint (*Calidris ruficollis*) as shorebirds frequently occurring within these areas.

The shorebird count data from Birds Australia Shorebird Areas at Cooke Point and Finucane Island is historical with the latest records from these areas dating to the early 1980s. The maximum numbers of individuals recorded from these areas during the period when counts were regular, ranges from 10s for some species and up to several hundred birds for other species. However, none of the shorebird counts within the database comprise ecologically significant numbers of any of the migratory species identified at Finucane Island.

To provide regional context, these numbers are in stark contrast to the 100s to 100,000s of individuals of these same species reported from the major intertidal areas further north where the importance of sites like Eighty Mile Beach and Roebuck Bay is recognised in their status as Ramsar[1] listed sites. It is also the case that since the last Birds Australia counts were undertaken in the 1980s the area at Finucane Island where the counts took place has been considerably reduced in size by construction activities.

The absence of reports of large numbers of the eighteen species of migratory shorebirds that use the Asian-Australasian flyway at the Finucane Island sites suggests that the immediate area around the disturbance envelope does not support an ecologically significant proportion of the population for these migratory species. However, the diversity of shorebird species recorded at Finucane Island (i.e. greater than 15) indicates that it may constitute important habitat within the flyway. For this reason, suitable mitigation and avoidance strategies have been developed to minimise and manage potential impacts to migratory shorebirds from development (see **Section 10.4**).

1 The Ramsar Convention or 'Convention of Wetlands of International Importance' aims to promote and protect wetlands throughout the world. The Ramsar Convention was first signed in Ramsar, Iran in 1971. The sites noted here are listed under this convention.

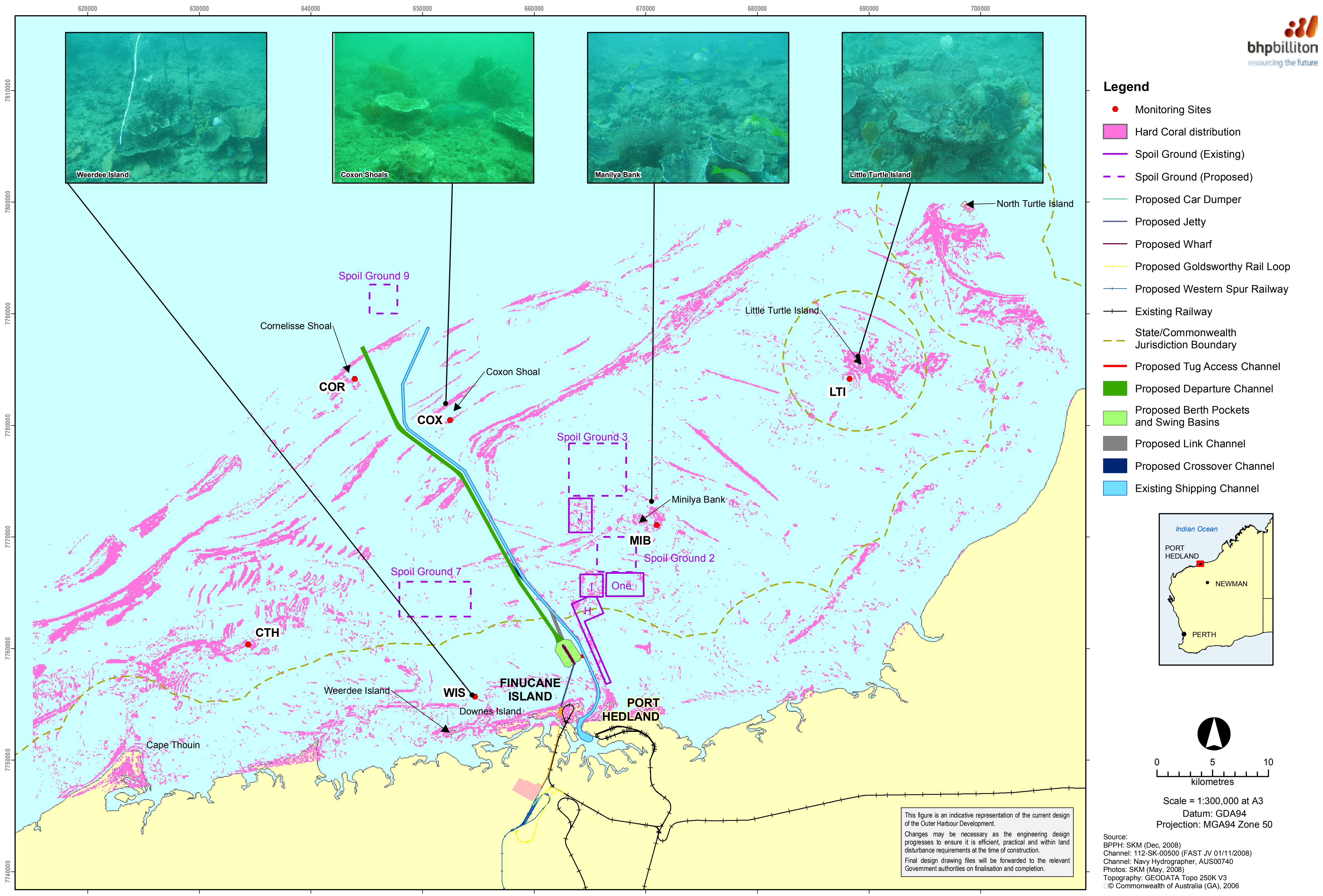


Figure 6.16 Hard Coral Distribution in the Study Area

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