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Section 5

Existing Terrestrial Environment

5 Existing Terrestrial Environment

5.1 Overview

The Pilbara region covers over 50,000,000 ha, with the coastal extent stretching from the Exmouth Gulf to Cape Keraudren (**Figure 5.1**). This area supports a diverse range of marine and terrestrial environments. Several areas in the Pilbara are isolated, rugged and recognised for their high conservation value, including Cape Range National Park, Millstream-Chichester National Park, Cape Keraudren Nature Reserve, Karijini National Park, and Rudall River National Park.

The terrestrial extent of the proposed Outer Harbour Development at Port Hedland includes Finucane Island, located immediately west of Port Hedland, and extends approximately 22 km inland (**Figure 5.1**). The coastal component of the Outer Harbour Development generally encompasses limestone ridges, mangroves and tidal mudflats, which transition to sandplains and floodplains with distance inland.

The terrestrial environment considered within this section focuses on areas landward of the high-water mark. Intertidal areas, such as mangroves and tidal mudflats are considered marine nearshore habitats and as such, are discussed within **Section 6**.

The existing terrestrial environment within the terrestrial study area includes previously disturbed areas such as the decommissioned Hot Briquetted Iron (HBI) Plant at Boodarie, the Finucane Island causeway and the BHP Billiton Iron Ore Operations located on Finucane Island (**Figure 1.1**). The southern extent of the terrestrial study area is pastoral land traversed by the Fortescue Metals Group (FMG) Railway, Great Northern Highway and other numerous roads and BHP Billiton Iron Ore's Port Hedland to Newman rail line.

5.2 Climate

5.2.1 Temperature

The Pilbara region is classified as sub-tropical, becoming more arid inland. Maximum temperatures exceeding 40°C and minimum temperatures around 25°C are often experienced in Port Hedland during the summer months. Winters are generally milder, with average temperatures ranging from a minimum 12°C to a maximum 29°C (Bureau of Meteorology (BoM) 2009a). Climatic averages recorded for Port Hedland are summarised in **Table 5.1** and **Figure 5.2**.

Table 5.1 – Summary of Climatic Averages for Port Hedland (Station 4032) 1942 – 2008

Month	Temperature[2] (°C)		Relative Humidity (%)		Mean Daily Evaporation[3] (mm)	Mean Monthly Rainfall (mm)	Wind Speed (km/hr)	
	Mean Daily Maximum	Mean Daily Minimum	9 am Mean	3 pm Mean			9 am Mean	3 pm Mean
Jan	36.4	25.5	56	51	10.5	58.3	14.5	25.5
Feb	36.2	25.4	59	53	9.6	94.3	14.3	23.4
Mar	36.8	24.5	50	45	9.3	48.3	15.1	21.4
Apr	35.2	21.3	41	37	8.7	23.7	16.8	19.5
May	30.6	17.3	41	36	7.4	28.0	19.6	18.1
Jun	27.5	14.1	43	35	6.4	21.4	20.6	17.6
Jul	27.1	12.3	40	32	6.6	10.8	20.6	18.5
Aug	29.1	13.1	36	31	7.4	5.2	19.9	19.9
Sept	32.2	15.3	33	31	8.9	1.2	18.2	22.2
Oct	32.2	18.3	33	35	10.6	0.9	17.8	25.2
Nov	36.2	21.3	37	39	11.4	2.6	15.8	26.4
Dec	36.6	24.0	46	45	11.4	18.3	15.0	26.7
Annual[1]	33.2	19.4	43	39	9.0	26.1	17.4	22.0

Source: BoM 2009a
[1] Approximation based upon mean daily values within each monthly period
[2] Temperature averages from 1948-2008
[3] Evaporation averages from 1967-2008

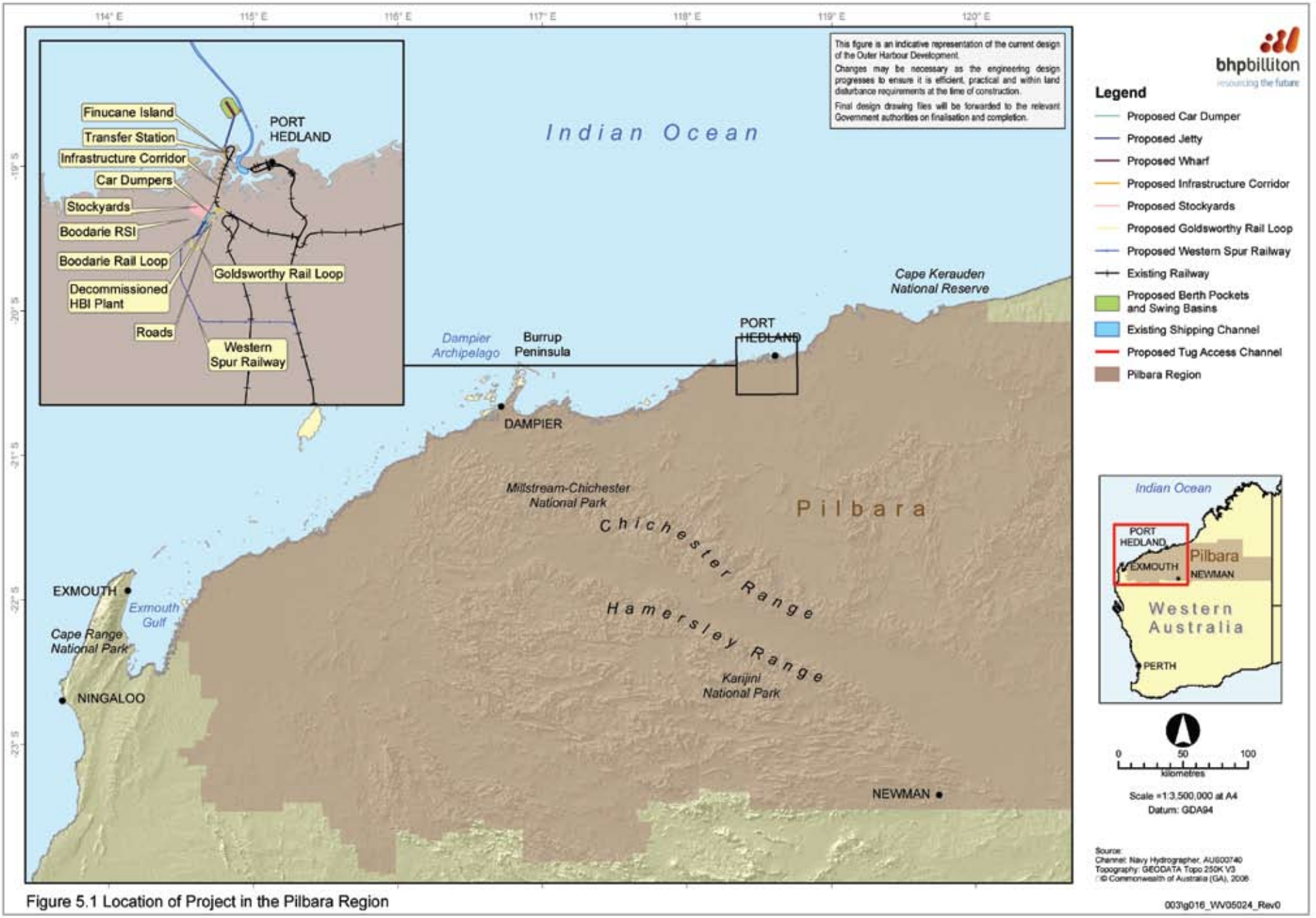


Figure 5.1 Location of Project in the Pilbara Region

5.2.2 Rainfall

Average annual rainfall for the Pilbara region varies between 250 and 400 mm, with many years reporting no significant rainfall events (BoM 2009a). The majority of rain occurs during the summer months (December to February), and is generally associated with scattered thunderstorms and tropical cyclones. A secondary peak in rainfall occurs in late autumn (May) resulting from tropical cloud bands which intermittently affect the Pilbara region. These events can also produce low maximum temperatures, particularly away from the coast (BoM 2009a).

Rainfall patterns in the Pilbara region vary dramatically due to the influence of tropical cyclones and lows. The Pilbara region receives an average of 20 to 30 thunderstorms per annum, with an average of 15 to 20 of those thunderstorms occurring near the coast. This can result in erratic and localised rainfall events that lead to tidal surges and localised flooding of Port Hedland's low lying coastal plain area (BoM 2009a).

5.2.3 Winds

Winds at Port Hedland vary seasonally in direction and strength. The windiest conditions are often experienced in summer, with winds generally prevailing from the north-west (BoM 2009a) (**Figure 5.3**). West and north-westerly winds dominate in summer, spring and most of autumn. In general, westerly winds are dominant in the morning, shifting to north-westerly in the afternoon, with an accompanying increase in speed (BoM 2009a). In winter, east to south-easterly winds are dominant in the mornings and shift to north-easterlies in the afternoon before easing in the evening in response to diurnal land temperature changes.

The average annual wind speed is approximately 18 kilometres per hour (km/h); however, wind gusts can exceed 80 km/h during thunderstorms. These wind gusts are generated by the interaction of high pressure belts and northern tropical low pressure systems (BoM 2009a).

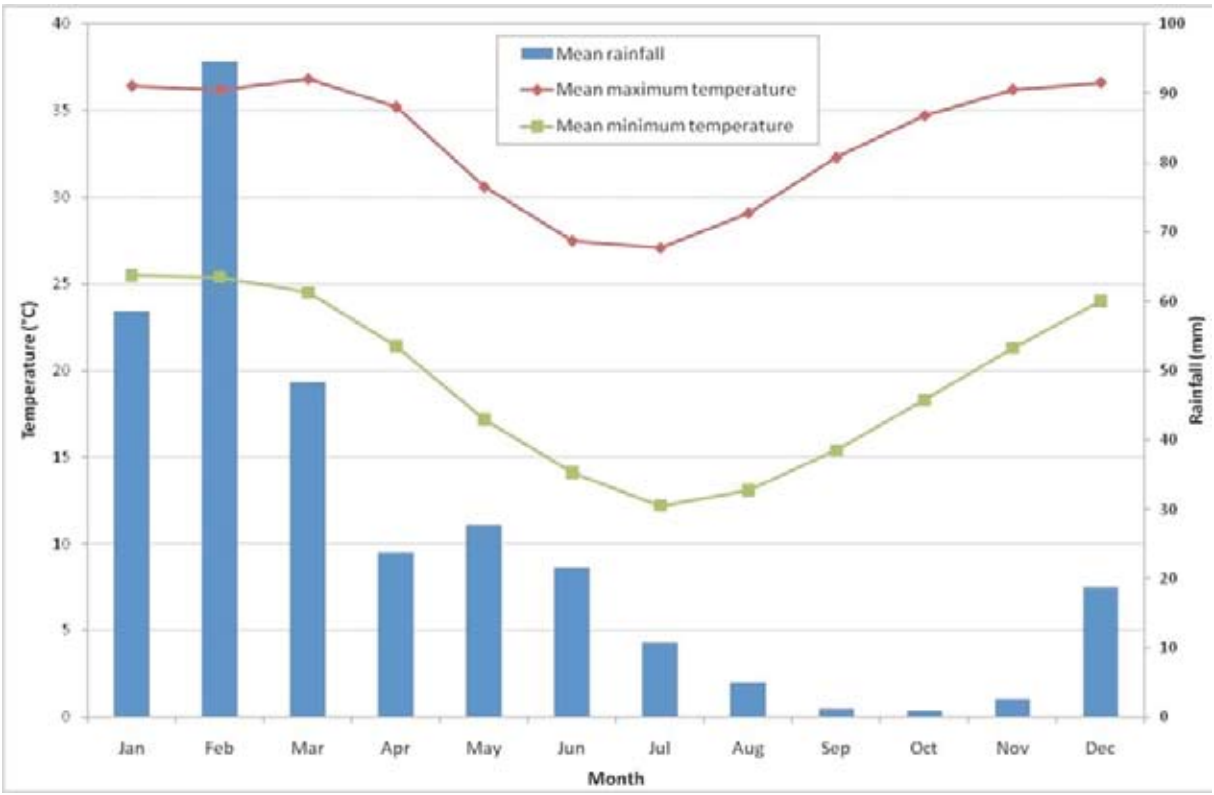
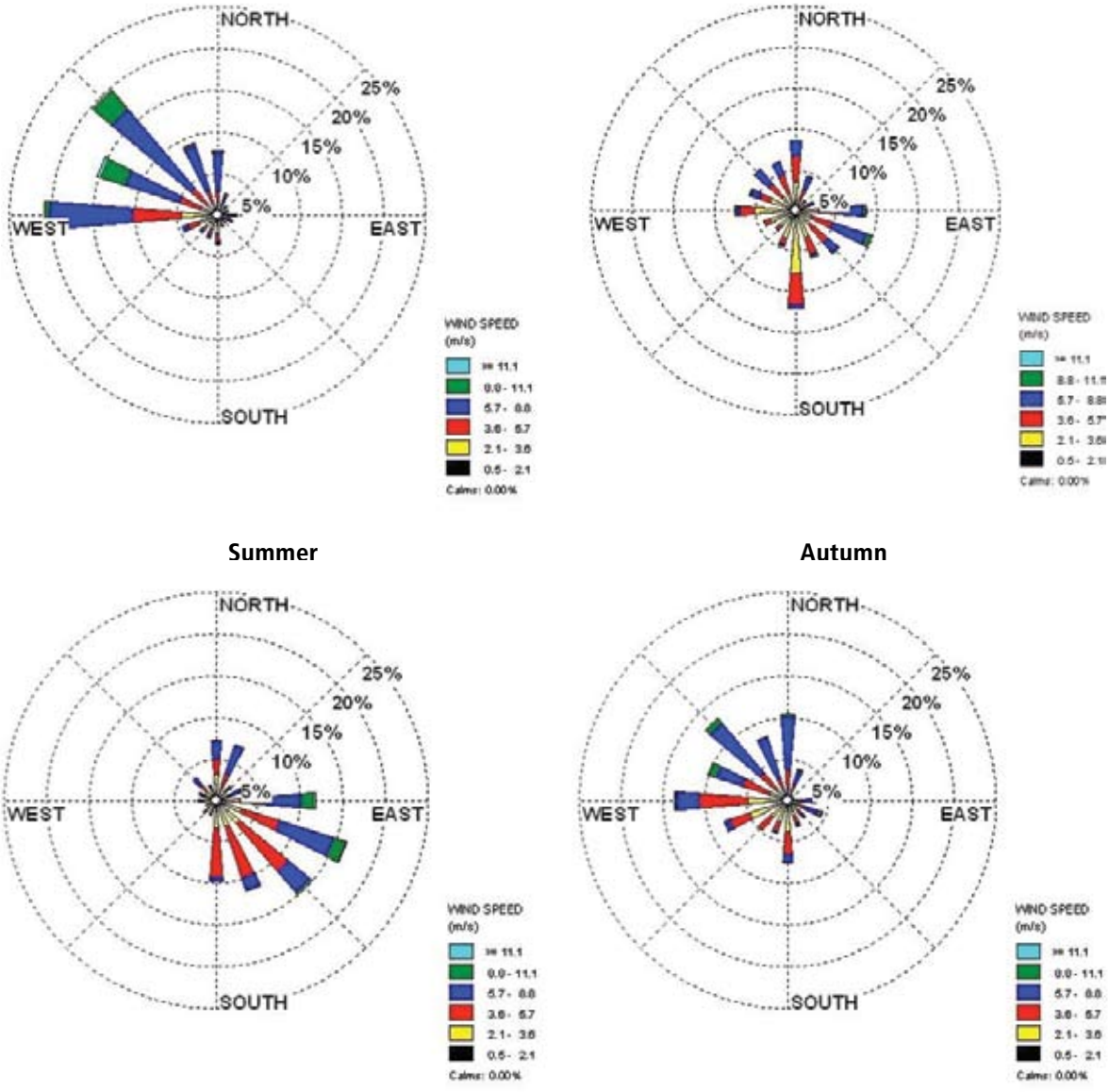


Figure 5.2 – Average Monthly Rainfall and Maximum and Minimum Temperatures for Port Hedland (Station 4032)

Source: BoM 2009a

Figure 5.3 – Seasonal Wind Roses for Port Hedland Airport for the Year 2007



Summer **Autumn**

Winter **Spring**

5.2.4 Tropical Cyclones

The coast from Port Hedland to Exmouth Gulf is considered the most cyclone prone area in Australia (BoM 2009b). In general, the cyclone season lasts from November to April, although tropical cyclones may occur outside this period. These cyclones normally develop over ocean waters to the north of Australia and follow a south-westerly course parallel to the north-west Australian coastline. On average, two thirds of these cyclones then change direction and head south-east, crossing the coast and moving inland, bringing heavy rainfall.

Tropical cyclones can be very intense, with recorded wind speeds in excess of 250 km/h and central pressures as low as 905 millibars (mb). There have been 49 cyclones between 1910 and 2007 that have caused gale-force winds at Port Hedland (BoM 2009b). 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).

5.3 Landforms, Geology and soils

5.3.1 Land Systems and Landforms

On a regional level, the terrestrial disturbance envelope is located within the Littoral, River and Uaroo land systems as defined by Van Vreeswyk *et al.* (2004) (**Table 5.2** and **Figure 5.4**). The Littoral land system encompasses the northern section of the disturbance envelope, including Finucane Island and the coastal margin; the River land system encompasses a small section of the proposed Western Spur rail line; and the Uaroo land system covers the remaining parts of the disturbance envelope to the south, including the stockyards.

5.3.2 Topography

The Pilbara landscape is typically flat and highly weathered with low rangelands occurring in the interior, representing a landscape that has remained largely unchanged for 100 million years (Western Australia Planning Commission (WAPC) 2003). The topography of the Port Hedland area is predominantly influenced by the Abydos Plain, which rises from the coastal lowlands to around 300 to 400 m above the mean sea level adjacent to the Chichester Range, located approximately 200 km south-west of Port Hedland.

The proposed infrastructure corridor and transfer station are located within a coastal area that is generally flat with gently sloping beaches, numerous headlands, and offshore islands (SKM 2009a). Finucane Island ranges from 1 to 10 m Australian Height Datum (AHD), with dunes along the northern shore (**Figure 5.5**). The proposed stockyards are located on a coastal plain, which is generally flat and low lying, ranging between 1 and 10 m AHD. The proposed Western Spur rail line is located in an area that gently elevates from the north to the south and south-east, ranging from 2 to 30 m AHD.

5.3.3 Geology and Soils

The Port Hedland area is located on the Holocene, Bossut Formation (**Figure 5.6**). This is a body of unconsolidated sedimentary soils described as sandy calcarenite, oolite and calcilutite, all of which outcrop discontinuously near the coast. The dunes, beach ridges, beaches and offshore bar deposits are predominantly marine, with the exception of the barrier dune system which is of Aeolian origin. Sections of this barrier dune system are generally stabilised by vegetation, and are common along this stretch of coast line.

Table 5.2 – Land Systems of the Terrestrial Disturbance Envelope

Land System	Description	Land System Composition	Approximate Area of Land System in the Terrestrial Disturbance Envelope	Distribution through the Pilbara Bioregion	Regional Percentage of Land System in Terrestrial Disturbance Envelope
Littoral	Bare coastal mudflats with mangroves on seaward fringes, samphire flats, sandy islands, coastal dunes and beaches.	70% Tidal flats 10% Samphire flats 5% Mangrove outer margins 5% Sandy plains and islands 4% Tidal channels 3% Coastal dunes 2% Alluvial plains <1% Limestone ridges <1% Beaches	230 ha	157,700 ha Common in coastal areas throughout the Pilbara	<1%
River	Active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.	15% Sandy levees and sand sheets 5% Upper terraces 50% Flood plains and lower terraces 10% Stony plains 20% Minor and major channels	55 ha	408,800 ha Common	<1%
Uaroo	Broad sandy plains supporting shrubby hard and soft spinifex grasslands.	82% Sandy/loamy plains 8% Pebbly plains 6% Tracts receiving sheet flow 3% Low rises 1% Calcrete plains <1% Low hills	3,985 ha	768,100 ha Very common in the north and far west of the Pilbara	<1%

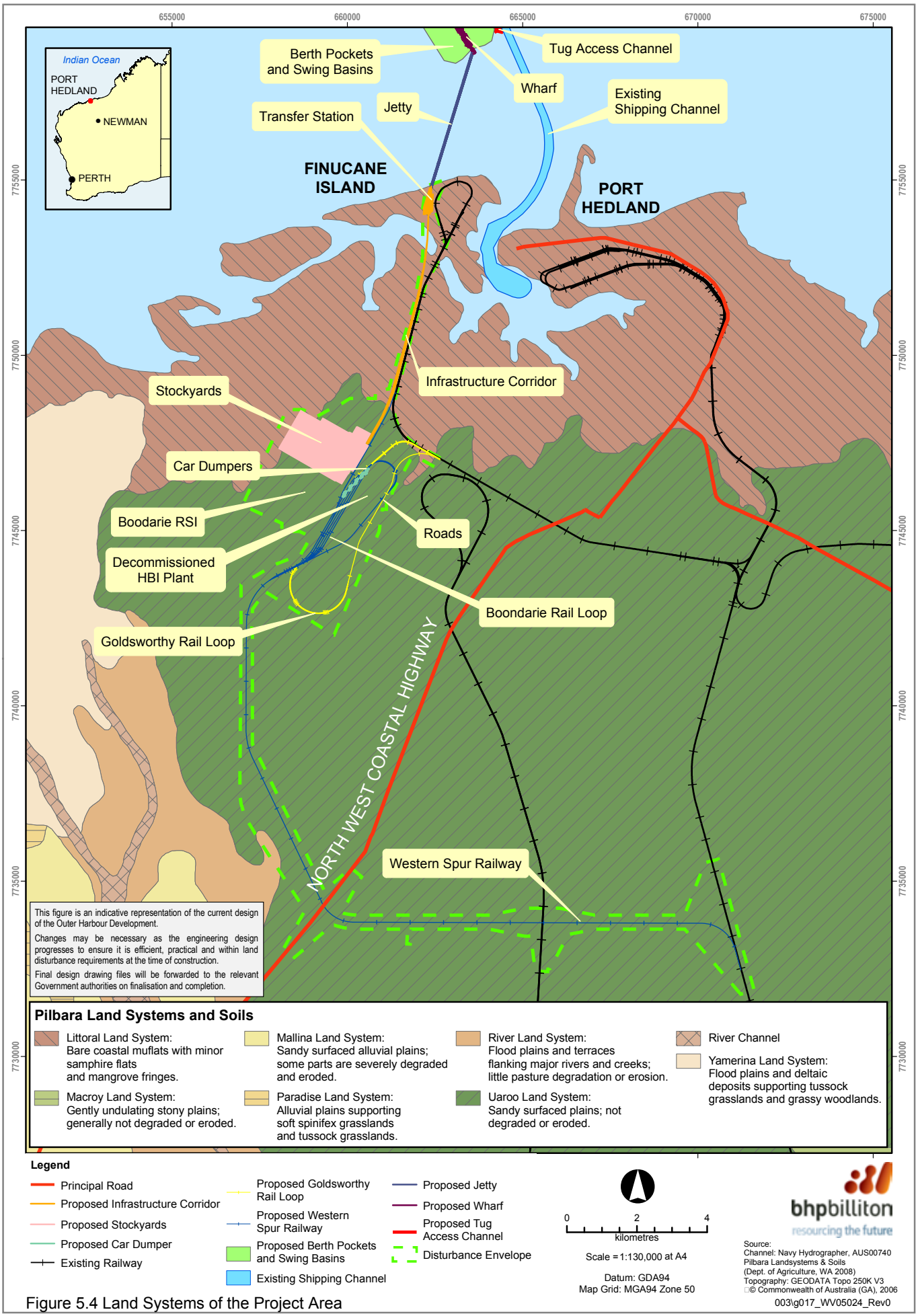


Figure 5.4 Land Systems of the Project Area

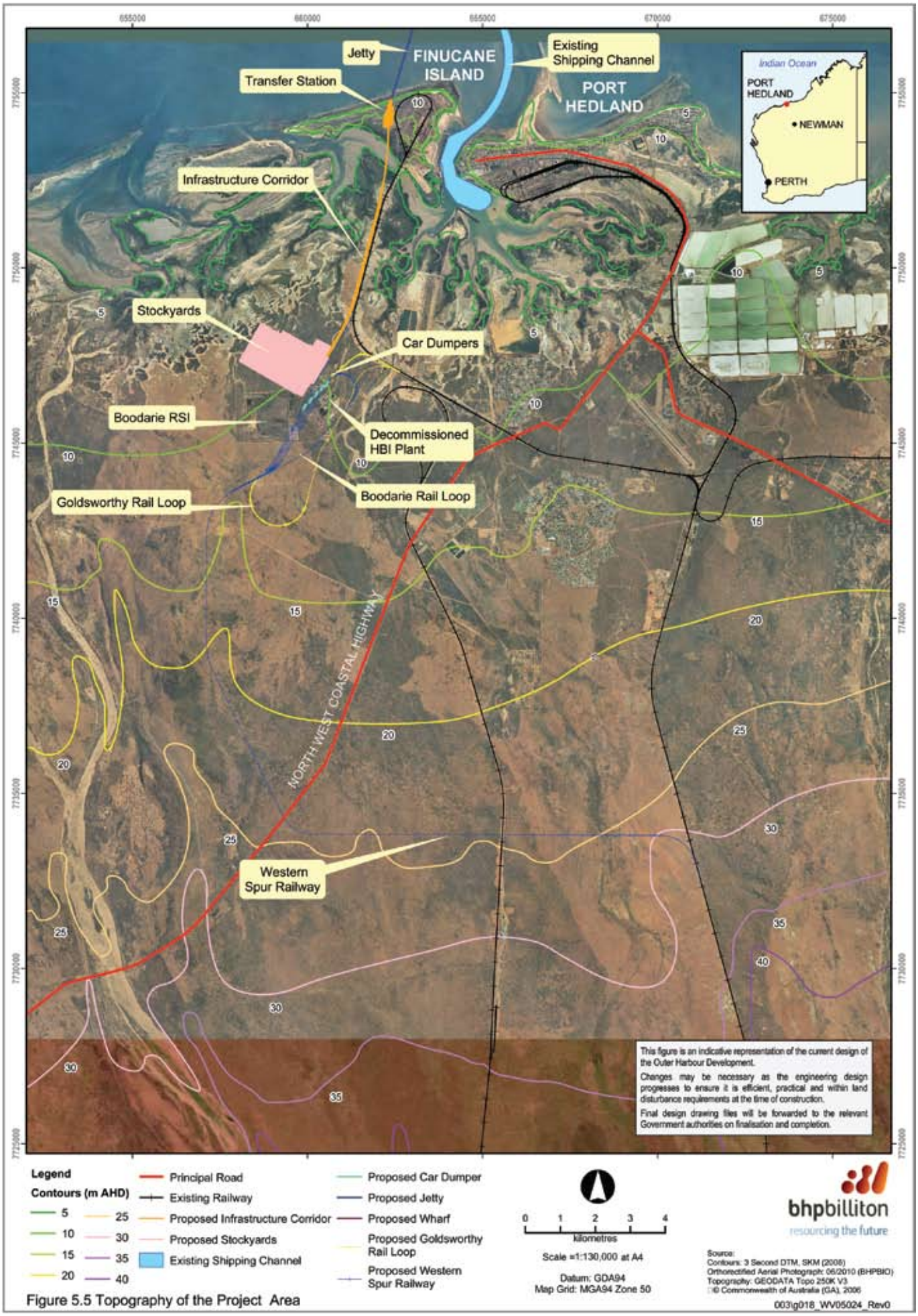


Figure 5.5 Topography of the Project Area

The coastal areas are primarily composed of saline muds and marine sands. Most of the soils within the terrestrial study area were formed by quaternary deposits, and are composed of the following units:

- intertidal mudflat deposits consisting of calcareous clay, silt and sand and mangrove swamp deposits that fringe numerous tidal creeks; and
- calcareous sand, silt and clay of supra-tidal flats, which separate the intertidal deposits from non-marine sediments.

Inland soils frequently include patches of hard, red alkaline earths and Pindan soils. The superficial geological profile of the terrestrial study area, as per the Geological Society of Western Australia (1983), is detailed in **Table 5.3**.

An environmental site assessment conducted at the former Goldsworthy Plant on Finucane Island confirmed that the natural superficial geological profile consisted of gravelly, medium to coarse grained, brown sand.

A geotechnical investigation conducted at Utah Point, east of the former Goldsworthy Plant on Finucane Island, confirmed that the natural geological profile consisted of mangrove flats/muds (brown to grey, sandy clay to clayey sand) and calcarenite (limestone) to a maximum depth of 1.7 m below ground level (mbgl) (Coffey Geotechnics 2007). Calcarenite was well cemented, coarse grained and white.

A geotechnical investigation conducted at the decommissioned HBI Plant and surrounding facilities at Boodarie confirmed that the natural geological profile consists of brown to orange clayey sand/sandy clay.

5.3.4 Acid Sulphate Soils

Acid sulphate soils (ASS) is a general term to include potential acid sulphate soils (PASS) and or actual acid sulphate soils (AASS). PASS are soils or sediments that have not undergone oxidation while AASS are soils or sediments that have undergone some oxidation to produce sulphuric acid (Department of Environment and Conservation (DEC) 2009a).

ASS can be soils, sediments and/or substrates that contain iron sulphides. In Western Australia, ASS are commonly associated with freshwater wetlands, tidal flats, flood plains, shallow estuarine marine deposits and saline sulphate rich groundwater (DEC 2009a).

An ASS risk map covering Port Hedland has been developed by the DEC (2006a) (**Figure 5.7**). In the *Pilbara Coastline Acid Sulphate Soils Risk Map* (DEC 2006a), the Port Hedland Inner Harbour and intertidal areas are identified as '*having a high to moderate risk of acid sulphate soils occurring within 3 metres of natural soil surface'*.

As part of the proposed Outer Harbour Development a desktop investigation to assess the potential occurrence of ASS in the disturbance envelope has been undertaken (SKM 2009a) in accordance with the DEC ASS guidelines (DEC 2009a). The preliminary ASS investigation completed for the project is included in **Appendix B12.** The desktop investigation indicated that there was potential for ASS on Finucane Island and along the proposed infrastructure corridor as these are located within areas mapped by the DEC (2006a) as having a high to moderate risk and moderate to low risk of ASS occurring, respectively. The proposed stockyards, rail loop and car dumper are located within 1 to 2 km of an area of moderate to low risk of ASS occurring.

Table 5.3 – Superficial Geological Profile of the Terrestrial Disturbance Envelope

Geological Unit	Description and Characteristics	Presence/Absence of Geological Units in Key Project Component Areas				
		Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway
Qhm	Mud, silt and mangrove flats (tidal)	✓	✓			
Qho	Older dune shelly sand	✓				
Qp	Dunal limestone	✓				
Qhs	Silty sand		✓	✓	✓	
Ql	Lime cemented beach conglomerate	✓				
Qps	Silty sand, red brown, clayey sand, abundant claypans		✓	✓	✓	✓
Qs	High level sands					✓
Qc	Clayey sand, abundant claypans					✓

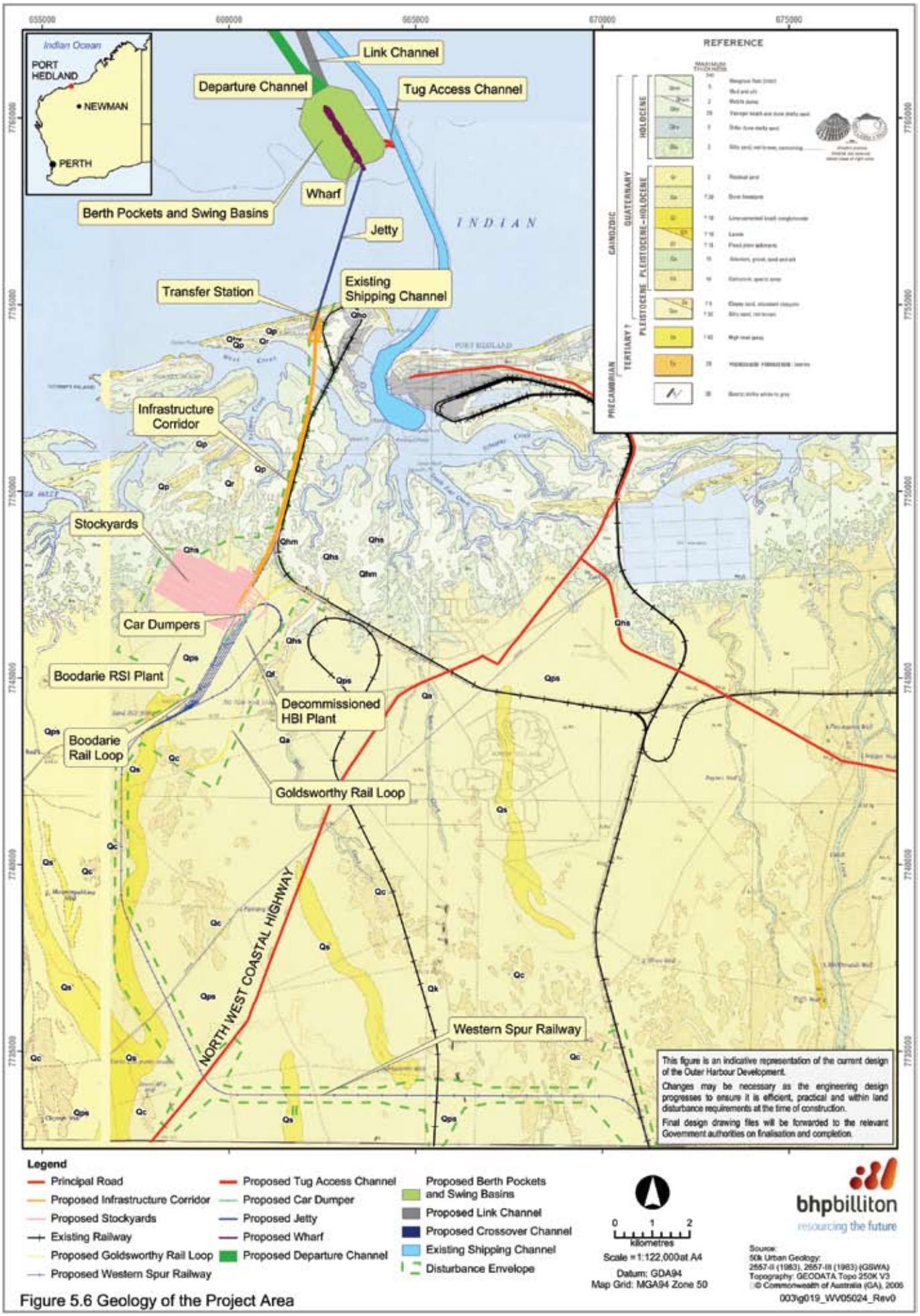


Figure 5.6 Geology of the Project Area

A number of recent land-based ASS investigations undertaken in the vicinity of the proposed Outer Harbour Development for other projects have identified either PASS or AASS within intertidal areas along the Port Hedland coastline, thereby suggesting ASS may potentially occur on Finucane Island and along the proposed infrastructure corridor. Preliminary intrusive investigations as part of BHP Billiton Iron Ore's Outer Harbour Development acid sulphate soils investigation (SKM 2009b) and the Dredged Material Management Area A detailed ASS investigation (SKM 2009c) have confirmed the presence of PASS in localised areas immediately to the west of the existing Finucane Island causeway. ASS are generally encountered in soils with higher clay content and soils in close proximity to creeks or intertidal areas that are frequently inundated. An ASS investigation undertaken for the Fortescue Metals Group (FMG) proposed Pilbara Iron Ore and Infrastructure Project confirmed ASS within the marine mud of the mangrove swamps (URS 2006). A study undertaken for the Port Hedland Port Authority's (PHPA) Utah Point development indicated that there was no AASS present within the study area, but identified that PASS could be expected in the northern portion of the Utah Point development's project site (Coffey Geotechnics 2007).

A summary of geomorphic or site description criteria used to assess the risk of ASS (DEC 2009a) in relation to areas of proposed excavation is provided in **Table 5.4**.

5.3.5 Contaminated Sites

A preliminary site investigation to determine and document potential contamination from current and past operations was conducted in the terrestrial disturbance envelope. This investigation concluded that there was a low risk of encountering soil or groundwater contamination within the disturbance envelope, with the exception of an area of the proposed stockyards and rail loop, where the decommissioned HBI Plant is located at Boodarie (SKM 2009b). This area has been subject to a detailed site investigation and is currently undergoing site remediation with the objective of rendering it suitable for future industrial development. Based on the site history information compiled for the Outer Harbour Development during the preliminary site investigation, no further detailed site investigation was considered warranted.

Table 5.4 – Potential for Acid Sulphate Soils at Proposed Infrastructure Areas

Areas Likely to Contain Acid Sulphate Soils[1]	Infrastructure Corridor and Finucane Island Transfer Station	Stockyards and Rail Loop	Western Spur Rail Line
Areas depicted on geology and/or geomorphological maps as geologically recent (Holocene) such as shallow tidal flats or tidal lakes, shallow estuarine, shallow marine deposits, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes, coastal alluvial valleys, wetlands, floodplain, waterlogged areas, scalded areas, sump land, marshes or swamps.	Yes – Holocene deposits present	No	No
Areas depicted in vegetation mapping as mangroves, wetland dependent vegetation such as reeds and paperbarks (*Melaleuca* spp.), areas where the dominant vegetation is tolerant of salt, acid and/or water logging, conditions e.g. mangroves, saltcouch, swamp-tolerant reeds, rushes, paperbarks and swamp oak (*Casuarina* spp.).	Yes – mangroves and salt tolerant vegetation are present throughout the majority of the area	No	No
Areas identified in geological descriptions or in maps as bearing acid sulphide minerals, former marine or estuarine shales and sediments, coal deposits or mineral sand deposits.	Yes – former marine sediments present	No	No
Areas known to contain peat or a build up of organic material.	No	No	No
Areas where the highest known water table level is within 3 m of the surface.	Yes	No	No
Land with elevation less than 5 m above Australian Height Datum (AHD).	Yes	No	No
Any areas in Western Australia (including inland areas) where a combination of all the following pre-disposing factors exist: organic matter, iron minerals, waterlogged conditions or a high water table, sulphidic minerals, deep estuarine sediments below ground surface.	Yes – waterlogged conditions or a high water table present	No	No

[1] *Source: DEC 2009a*

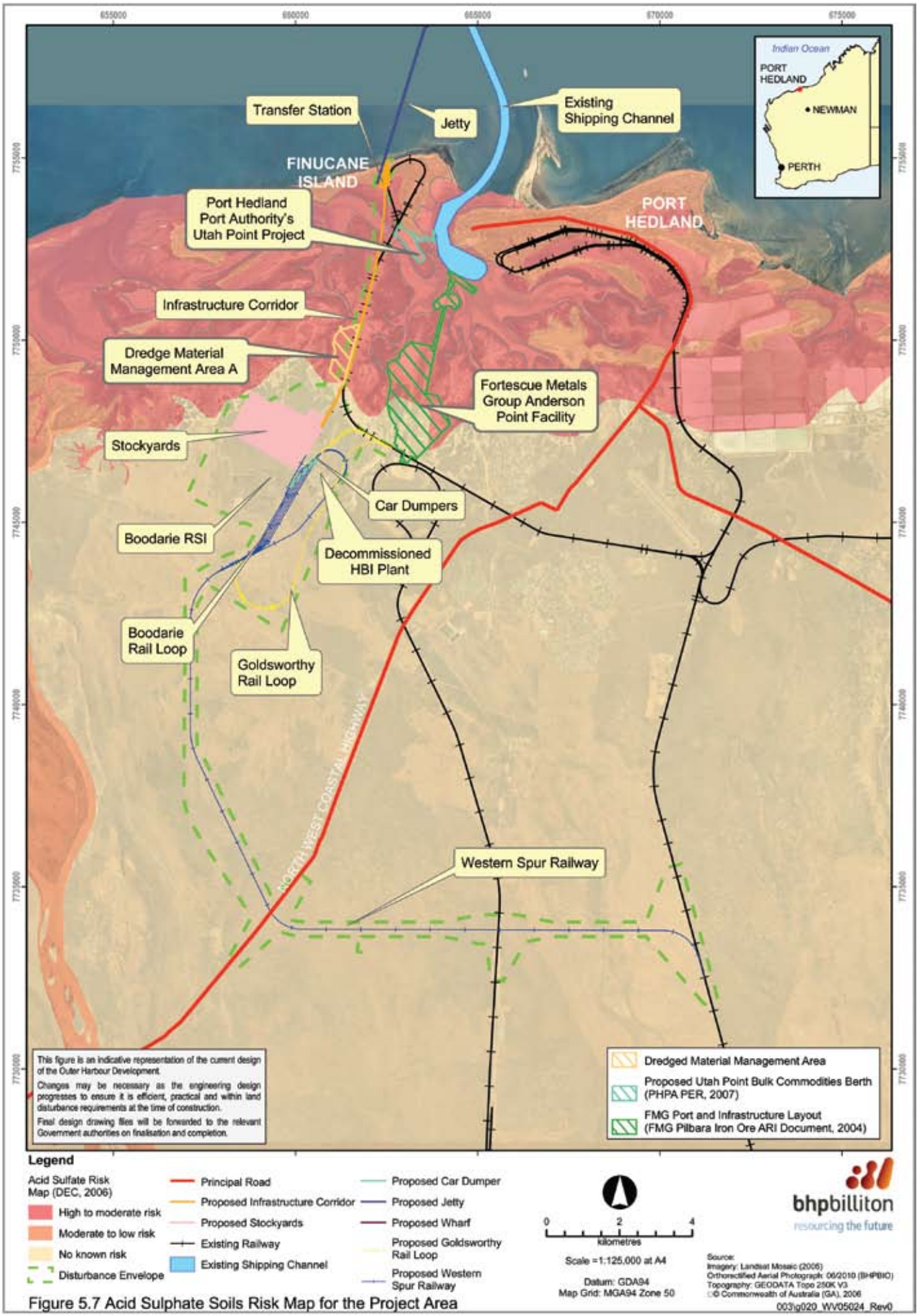


Figure 5.7 Acid Sulphate Soils Risk Map for the Project Area

5.4 Catchment Hydrology and Groundwater

5.4.1 Surface Hydrology

A review of the surface water conditions of the Port Hedland area has been undertaken (SKM 2009d). The terrestrial disturbance envelope is located in two catchments, the Coastal Catchment and the South West Creek Catchment. A third catchment area, the Turner River Catchment, is located approximately 2 km to the west of the proposed Western Spur rail line (**Figure 5.8**).The Port Hedland Area contains several creeks along the coast between the Turner River Catchment and the De Grey River Catchment that converge to create a natural anchorage at Port Hedland. The ephemeral South West Creek and South Creek are the dominant natural watercourses that drain into the Port Hedland Harbour (WAPC 2003) (**Figure 5.8**). These creeks are dry for the majority of the year; however, as is the case with other ephemeral rivers of the Pilbara region, significant runoff is generated after heavy rainfall, often overflowing and inundating the coastal plain. One billabong, Coolarin Pool, is located in the south-east of the terrestrial study area.

South West Creek

South West Creek is approximately 53 km in length, and has an estimated catchment area of 39,500 ha (Global Environmental Modelling Systems (GEMS) 2000). This catchment is relatively flat with poorly defined stream systems, resulting in indistinguishable catchment boundaries and flow paths in the lower reaches. The primary flow channels have discontinuities and are connected by overland flow paths that experience relatively shallow, slow moving sheet flow (GEMS 2000).

South West Creek flows in a generally northerly direction and discharges on the western side of Anderson Point (**Figure 5.8**). The creek intersects with the existing Goldsworthy rail line, where the majority of flow is channelled in a northerly direction through a series of drainage culverts under the rail embankment and minor flows are channelled to the west into Salmon Creek under the existing decommissioned HBI Plant conveyor via a diversion channel (**Figure 5.8**).

South Creek

South Creek is approximately 8.5 km in length and has an estimated catchment area of 2,300 ha (GEMS 2000). The South Creek Catchment, much like the South West Creek Catchment, lacks a defined stream system (GEMS 2000).

South Creek flows in a northerly direction and discharges on the eastern side of Anderson Point (**Figure 5.8**). At the intersection of South Creek with the existing Goldsworthy rail line, which occurs approximately 5 km east of the proposed rail loop, flow is channelled through drainage culverts under the rail embankment. South Hedland is located within the eastern floodplain of South Creek.

The proposed Western Spur rail line route is predominantly located to the west of the South West Creek Catchment along the edge of its flood plain. The southern section of the railway spur (east-west alignment) crosses a number of major tributaries flowing into both the South West Creek and South Creek. This area is subject to localised flooding from the South West Creek and South Creek.

Surface Water Quality

Stream salinity in the Pilbara region typically consists of calcium, bicarbonate, chloride and sodium. These salts are derived from the weathering of soil and rock. The majority of Pilbara waterways are fresh with low nutrient levels drawing from the ranges to the south of the Pilbara region (DoE 2004a).

Monitoring of surface water within South West Creek indicates pH varies from 7.9 to 8.7 and total dissolved solids (TDS) varies from 330 to 260,000 mg/L (BHP Billiton Iron Ore 2005, 2008c).

Tides

Semi-diurnal tides are experienced within the Port Hedland Harbour with a spring tidal range of 6 m and a neap tidal range of approximately 1.5 m. The lower neap tides are limited to the tidal creeks and the lower lying intertidal mudflats. In contrast, the spring tides reach into the higher mudflat areas up to approximately 2.5 to 3 m AHD (PHPA 2003). Tidal influence is described in more detail in **Section 6**.

Storm Surge

Regular cyclone activity and induced ocean storm surge events (due to the combination of low atmospheric pressure and waves) have exposed both South West Creek and South Creek to regular flooding. The close proximity of both Wedgefield and South Hedland to South Creek has resulted in both towns being subject to inundation during storm surge events (**Figure 5.8**).

The GEMS (2000) 'Greater Port Hedland Storm-Surge Study' assessed the combined effects of storm-surge and riverine flooding in Port Hedland using computer modelling. To the north of the existing Goldsworthy rail line, storm surge is considered the dominant flooding mechanism due to the barrier this railway poses to inland penetration of storm surge waters.

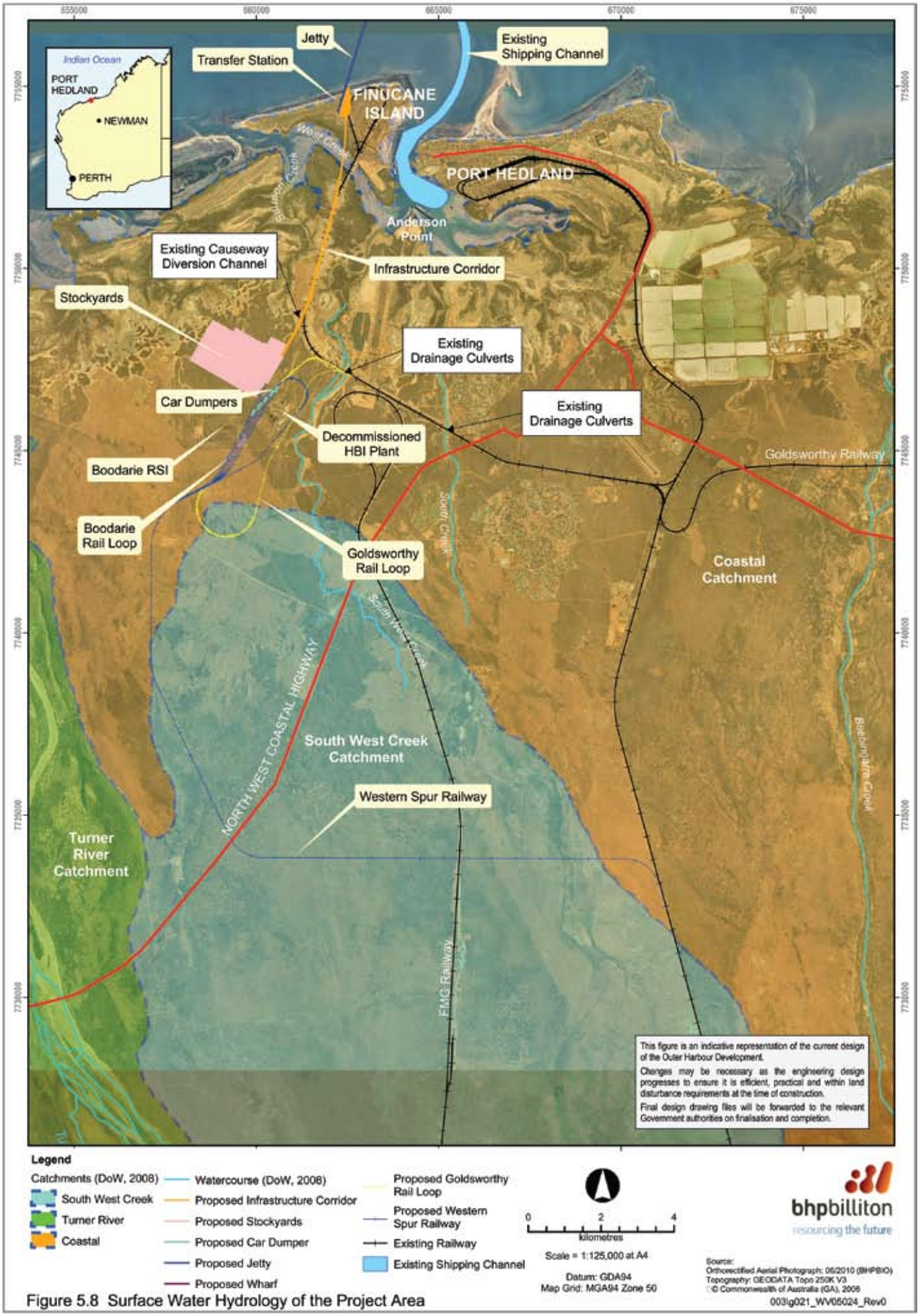


Figure 5.8 Surface Water Hydrology of the Project Area

South of this barrier, riverine flooding becomes the dominant flooding mechanism. Peak storm-surge levels generated by GEMS (2000) for 1 in 50 and 1 in 100 Average Recurrence Interval (ARI) events were highest over mudflats and sandy lowlands. For a 1 in 100 ARI, storm surge levels of 5 m and 6 m AHD were generated for Anderson Point and the existing Goldsworthy rail line, respectively (GEMS 2000).

Flooding

South West Creek and South Creek have historically flooded upstream of the existing Goldsworthy Railway embankment, due to the rail line embankment acting as a barrier to creek flows discharging to the ocean. A large capacity diversion channel has been constructed on the upstream side of the Goldsworthy rail line diverting flood waters from South West Creek to the west (Aquaterra 2004) (**Figure 5.8**).

Riverine flooding of South West Creek and South Creek was assessed as part of the GEMS (2000) storm-surge study. For South West Creek, design 1 in 50 year and 1 in 100 year ARI peak discharges from the existing Goldsworthy Railway were estimated to be 1,233 cubic metres per second (m^3/s) and 1,902 m^3/s, respectively. For South Creek, design 1 in 50 and 1 in 100 year ARI peak discharges from the existing Goldsworthy Railway were estimated to be 234 m^3/s and 383 m^3/s, respectively.

Surface water flows within South West Creek and South Creek have been altered as a result of railway infrastructure, which acts as a barrier between the two creeks. Surface water modelling has demonstrated a shift in water flow volumes, reducing flood conveyance into the lower reaches of South West Creek and increasing peak flood levels in South Creek (SKM 2008). Key findings from the hydrological investigation undertaken by SKM (2008) included:

- peak flood levels for South West Creek are reduced by up to 130 mm for the design 1 in 100 year ARI and 70 mm for the design 1 in 50 ARI;
- peak flood levels for the design 1 in 100 ARI flood event are decreased in South West Creek at the decommissioned HBI Plant by 100 mm; and
- diversion bunds at the South West Creek crossing were likely to concentrate flows to the creek and increase peak flow levels by 100 to 300 mm immediately downstream of the embankment.

Peak flood levels for the design 1 in 50 year and 1 in 100 year ARI flood event are shown in **Figure 5.9** and **Figure 5.10**, respectively.

5.4.2 Groundwater

Groundwater Resources

A search of the Department of Water (DoW) register of groundwater bores in the Port Hedland area indicated that 71 registered bores exist within the vicinity of the proposed Outer Harbour Development (**Figure 5.11**), the majority of which are used for livestock purposes. No proclaimed drinking water sources occur within the terrestrial study area. Port Hedland and South Hedland are supplied with drinking water from the Yule River and De Grey River borefields, which are located approximately 45 km to the west and 65 km to the east of Port Hedland, respectively.

Hydrogeology

A review of the groundwater conditions of the Port Hedland area has been undertaken (SKM 2009d). The Port Hedland area, including the proposed Outer Harbour Development area, lies within coastal plain alluvial deposits. The majority of the Port Hedland coastal region is comprised of superficial sediments with minor occurrences of fractured and weathered rocks of low permeability, namely sandstone, adjacent to South West Creek (DoW 2006). The occurrence of groundwater in the Port Hedland area is associated with sand and gravel units within the alluvium, augmented by weathered basement and/or calcrete.

In the Port Hedland area, the majority of the recharge of the alluvial aquifer is likely to be a result of infiltration during storm events. This is due to the highly permeable nature of the majority of the soil material overlying this alluvial aquifer (SKM 2009d). Some localised recharge to the alluvial aquifer may also occur when surface water levels in creeks are higher than the surrounding groundwater level. Groundwater levels are expected to vary with tidal fluctuation in areas close to the coastline.

Depth and Direction of Flow

Groundwater elevation contours and the anticipated hydrological gradient for groundwater flow in the vicinity of the proposed Outer Harbour Development are presented in **Figure 5.12**. The elevation of groundwater ranges from approximately 20 m AHD (southern extent of the Outer Harbour Development) to less than 1 m AHD (near the coast), suggesting that groundwater flows north, north-west towards the coast with a gentle hydraulic gradient. This figure was constructed using depth to groundwater information from the DoW Water Information (WIN) Database search of previous local monitoring investigations (BHP Billiton Iron Ore 2005).

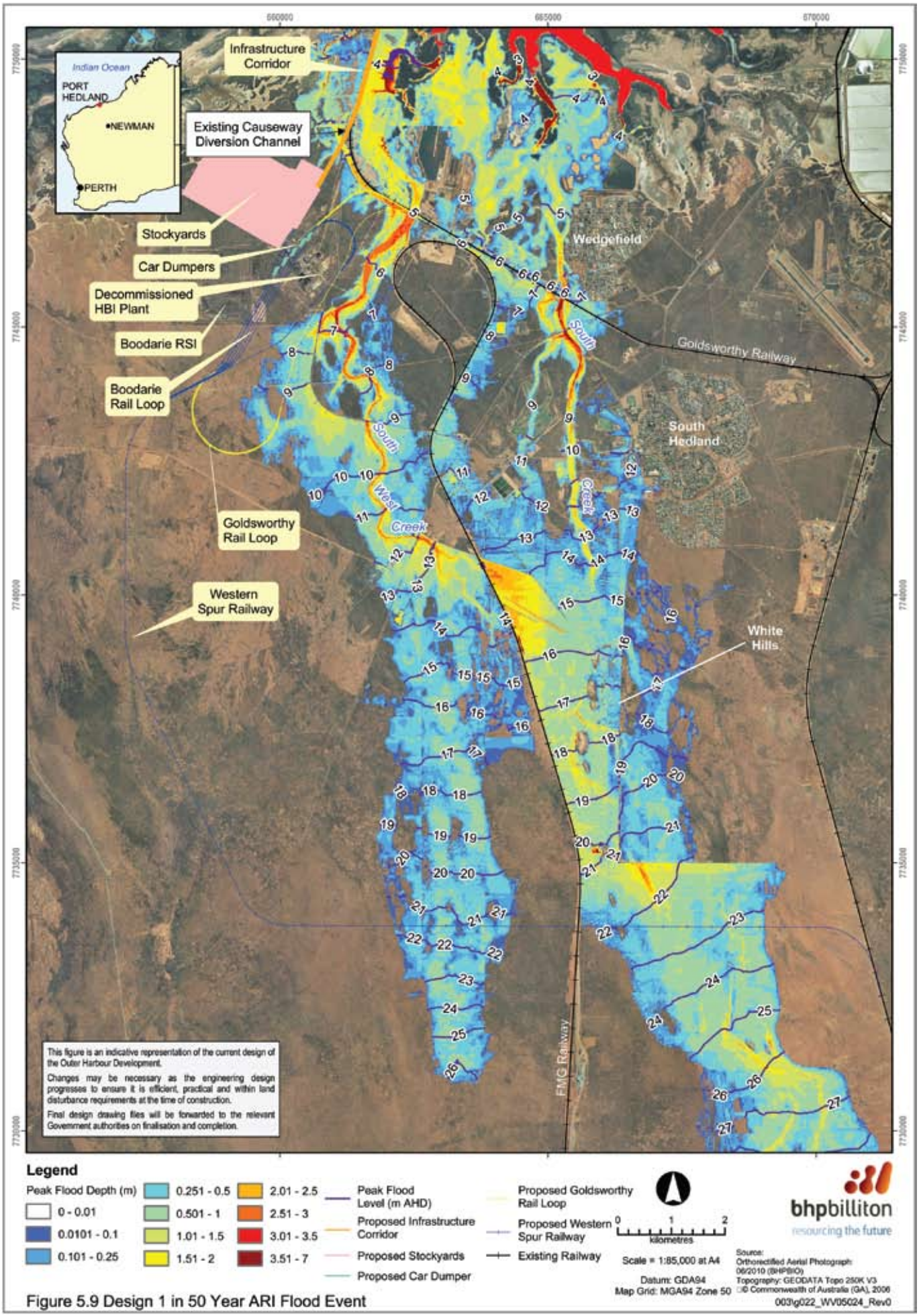


Figure 5.9 Design 1 in 50 Year ARI Flood Event

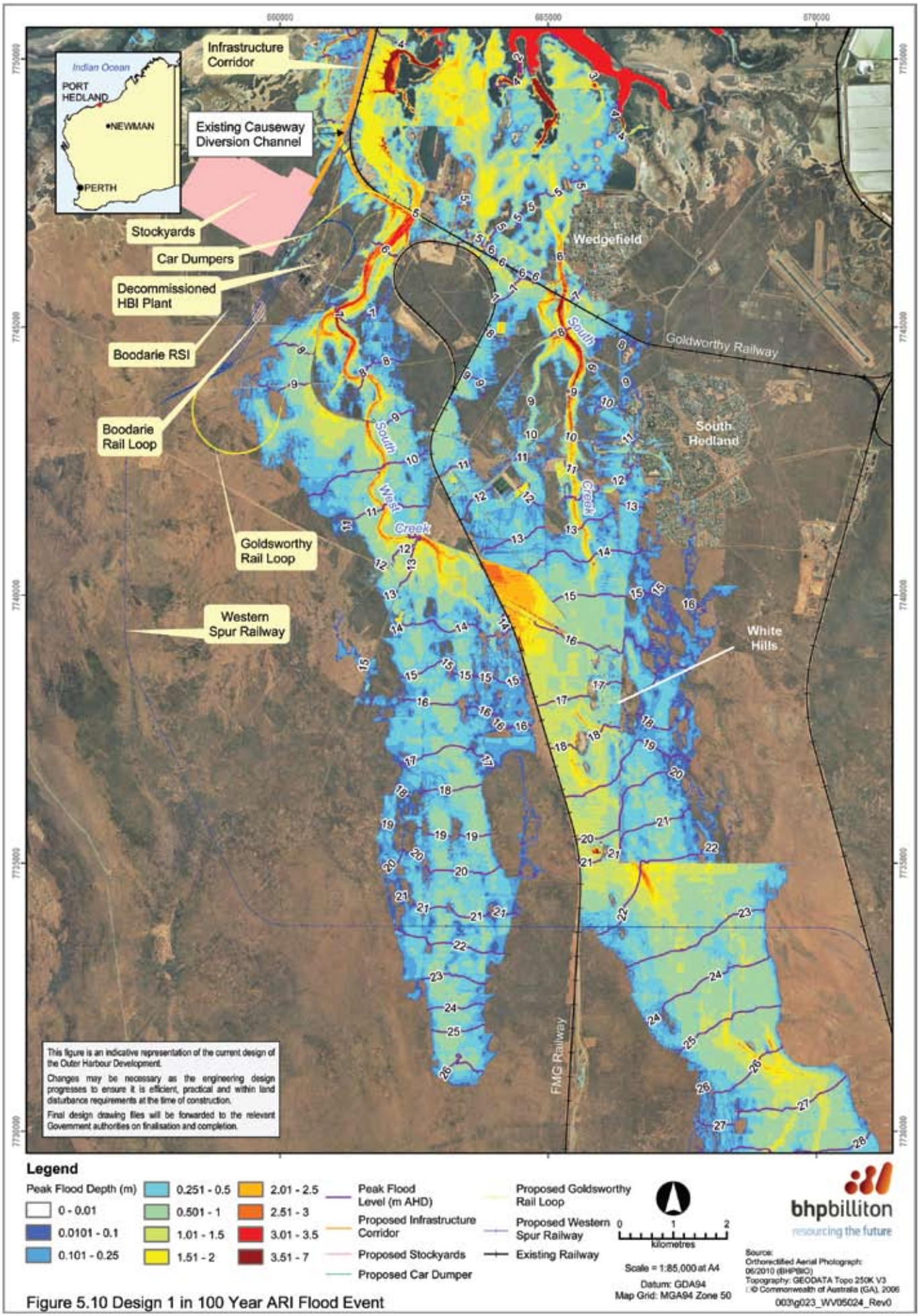


Figure 5.10 Design 1 in 100 Year ARI Flood Event

Monitoring results from groundwater bores on Finucane Island show that the elevation of groundwater is typically 1 to 3 m AHD. The inferred regional groundwater flow direction is radial from the island centre to the shore.

Monitoring results from groundwater bores within the decommissioned HBI Plant indicate that the elevation of groundwater varies from 3 to 5 m AHD in the Plant site and from 2 to 3 m AHD closer to the ocean (BHP Direct Reduced Iron 1994; BHP Billiton Iron Ore 2005, 2008c). In response to rainfall recharge of the shallow unconfined groundwater aquifer, groundwater elevations in the Boodarie area vary seasonally by up to 2 m (BHP Direct Reduced Iron 1994; BHP Billiton Iron Ore 2008c). Groundwater elevations usually peak in April (which appears to be due to high rainfall at the beginning of the year) and generally decline for the remainder of the year.

Groundwater Quality

Groundwater quality information is restricted to areas which have been the subject of groundwater monitoring, namely Finucane Island and the decommissioned HBI Plant at Boodarie. Groundwater quality information discussed in this section is restricted to pH and salinity. The pH of groundwater recorded across Finucane Island ranged from 6.7 to 8.4 indicating neutral to slightly alkaline conditions. The pH of groundwater in the decommissioned HBI Plant site varies between 6.7 and 8.4 (BHP Billiton Iron Ore 2005). Groundwater salinity on Finucane Island varies from 940 to 61,000 mg/L TDS. Salinity at the decommissioned HBI Plant site ranges from 960 to 80,000 mg/L TDS (BHP Direct Reduced Iron 1994; BHP Billiton Iron Ore 2005, 2008c). The extreme salinity ranges recorded for Finucane Island and the decommissioned HBI Plant site at Boodarie reflect the tidal influence on groundwater near the coastline. The salinity of groundwater decreases with distance inland from the coast (BHP Billiton Iron Ore 2005).

5.5 Biological Environment

5.5.1 Biogeography

The Outer Harbour Development is located within the Pilbara bioregion, one of 85 bioregions recognised under the Interim Biogeographic Regionalisation for Australia (Environment Australia 2000). The Pilbara bioregion comprises four sub-regions: the Hamersley, Chichester, Fortescue Plains and Roebourne sub-regions (Environment Australia 2000). The project is located within the north-eastern coastal section of the Roebourne sub-region, which is defined as:

> '*Quaternary alluvial and older colluvial coastal and sub-coastal plains with a grass savannah of mixed bunch and hummock grasses, and dwarf shrub steppe of* Acacia stellaticeps *or* A. pyrifolia *and* A. inaequilatera. *Uplands are dominated by* Triodia *hummock grasslands. Ephemeral drainage lines support* Eucalyptus victrix *or* Corymbia hamersleyana *woodlands. Samphire, Sporobolus and mangal occur on marine alluvial flats and river deltas. Resistant linear ranges of basalts occur across the coastal plains, with minor exposures of granite. Islands are either Quaternary sand accumulations, or composed of basalt or limestone, or combinations of any of these three. Climate is arid (semi-desert) tropical with highly variable rainfall, falling mainly in summer. Cyclonic activity is significant, with several systems affecting the coast and hinterland annually.*' (Kendrick & Stanley 2001).

The Roebourne sub-region covers an area over 2,000,000 ha, of which 2,539 ha is within the disturbance envelope of the project (less than 0.1% of the sub-region).

The disturbance envelope is in the Abydos Plain, which forms part of the Fortescue Botanical District in the Eremaean Botanical Province of Western Australia (Beard 1975).

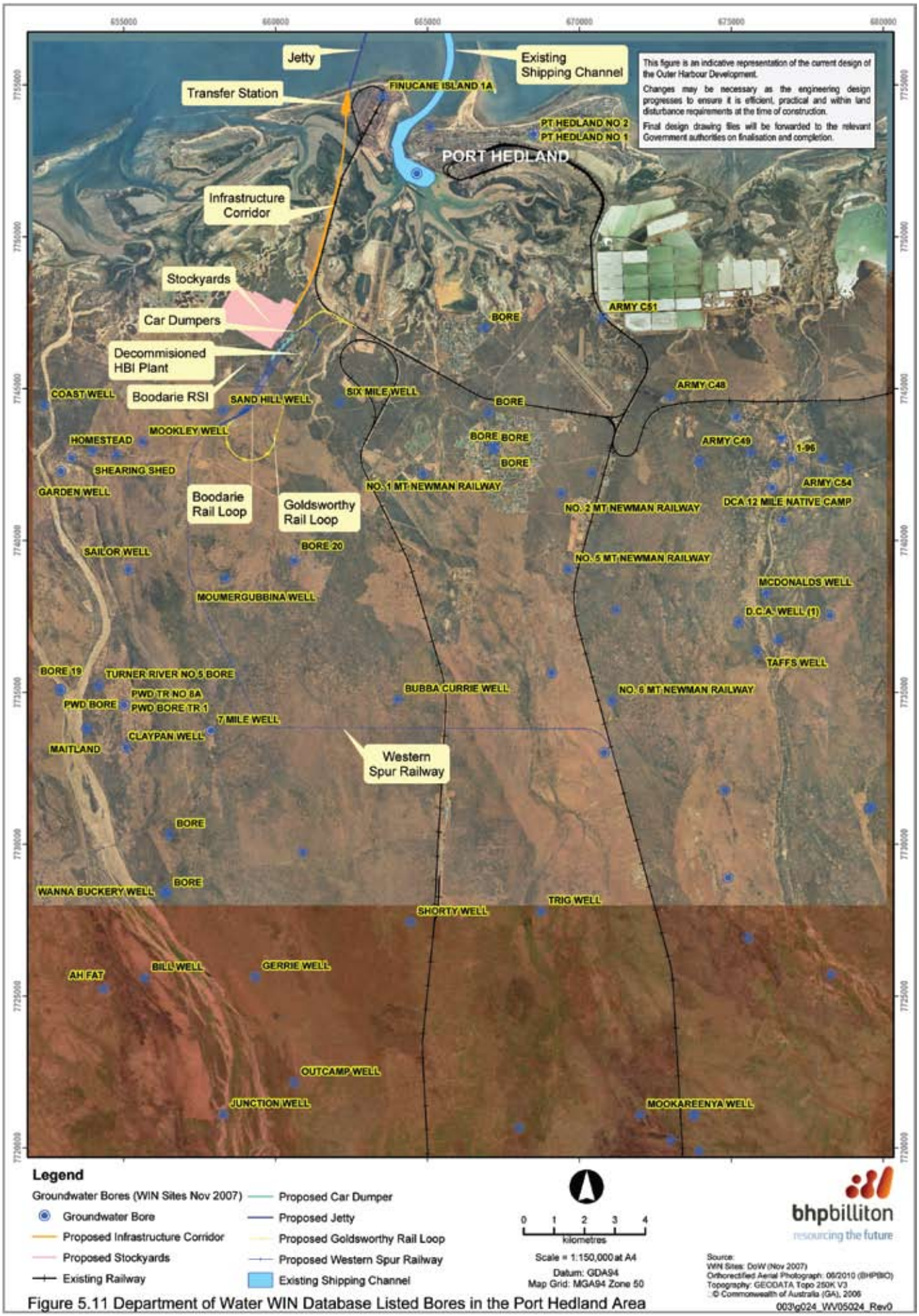


Figure 5.11 Department of Water WIN Database Listed Bores in the Port Hedland Area

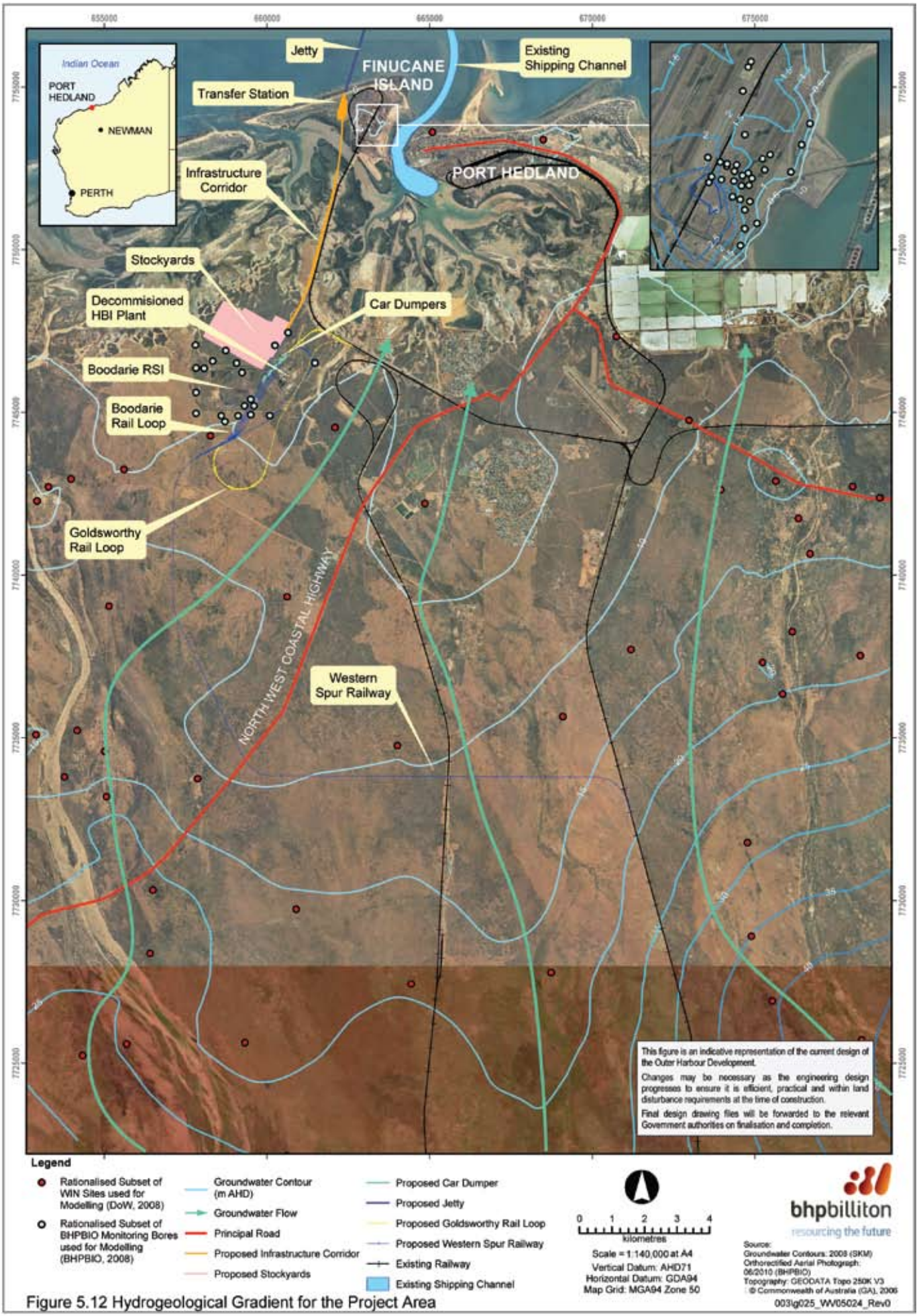


Figure 5.12 Hydrogeological Gradient for the Project Area

5.5.2 Biodiversity

The Pilbara region has been nominated by the Australian Government's Threatened Species Scientific Committee as one of 15 national biodiversity hotspots, known as the Hamersley-Pilbara Hotspot (DEWHA 2009a). National Biodiversity Hotspots are defined as:

> *'areas that support natural ecosystems that are largely intact and where native species and communities associated with these ecosystems are well represented. They are also areas with a high diversity of locally endemic species, which are species that are not found or are rarely found outside the hotspot'* (DEWHA 2009a)

According to the DEWHA (2009a), the natural values of National Biodiversity Hotspots are under growing threat from current, planned or potential management activities, and require active conservation management.

Characteristics of the Pilbara region that contribute to its National Hotspot status as per the DEWHA (2009a) include:

- the Pilbara provides habitat for a number of threatened, endemic and fire-sensitive species and communities;
- the Pilbara is home to small mammals , such as the Little Red Antechinus (*Dasykaluta rosamondae*) and the Western Pebble-mound Mouse (*Pseudomys chapmani*);
- the arid climate favours endemic reptiles including gecko and goanna species; and
- the coastal islands are refuges for vulnerable species that are rare or extinct on the mainland, such as the Western Chestnut Mouse (*Pseudomys nanus*), and are breeding sites for turtles and seabirds.

5.5.3 Existing and Proposed Reserves and Conservation Areas

No existing or proposed Commonwealth or State conservation reserves/areas of terrestrial nature are located within 50 km of the Outer Harbour Development.

5.5.4 Flora and Vegetation

Relevant Surveys

A two-season flora and vegetation survey was undertaken for the project by ENV Australia (ENV), with a summer season survey in October 2007, and a winter season survey in May 2008 (ENV 2009a). An additional flora and vegetation survey was undertaken in October 2008 to cover a portion of the terrestrial study area adjacent to the existing Goldsworthy rail line (ENV 2009b). The flora and vegetation surveys conducted by ENV constituted a 'Level Two Survey' as per the EPA's Guidance Statement No. 51 (EPA 2004a), and included vegetation community mapping, assessment of vegetation condition and searches for Declared Rare Flora and Priority Flora. The area surveyed by ENV is shown in **Figure 5.13**. This terrestrial study area is larger than that depicted by the disturbance envelope in previous figures as it encompassed a number of rail options that were under consideration during pre-feasibility studies. A targeted Priority Flora survey within the terrestrial study area was also undertaken in March 2009 following the high rainfall (236 mm) received between December 2008 and March 2009 (ENV 2009c).

The flora and vegetation reports prepared by ENV for the project are included in **Appendices B13** and **B14.**

Previous flora and vegetation surveys that have encompassed parts of the disturbance envelope include those conducted for:

- the Rapid Growth Project 5 (RGP5) Dredge Material Management Area A (Biota 2008); and
- the decommissioned HBI Plant at Boodarie (Mattiske 1994).

These surveys included broad-scale vegetation community mapping, and searches for Declared Rare Flora and Priority Flora.

Other flora and vegetation surveys undertaken in the vicinity of the project include those at Finucane Island (Biota 2007), Port Hedland (Biota 2006a), Lumsden Point (Biota 2009; ENV 2009d), and the FMG Railway line (Biota 2004a).

Vegetation

A total of 34 vegetation communities (excluding areas devoid of native vegetation such as disturbed, washout and bare sand areas) were mapped within the terrestrial study area, of which 19 are present within the disturbance envelope (ENV 2009a, 2009b). Previous vegetation mapping for the area was broad-scale, and resulted in only nine vegetation communities being mapped within the vicinity of the project (Mattiske 1994). The vegetation communities, descriptions and vegetation condition determined in the 2008 survey (ENV 2009a, 2009b) are detailed in **Table 5.5** and are shown in **Figure 5.13**. Vegetation communities found within intertidal areas (i.e. those mapped by ENV as Mangroves, Samphire A and Samphire B) are discussed in greater detail in **Section 6**.

The three most prevalent vegetation communities in the terrestrial study area are Sandplain N, Sandplain I and Sandplain Q, which represent approximately 12%, 11% and 10%, respectively, of the study area (ENV 2009a, 2009b) (**Figure 5.13**). Areas devoid of native vegetation included disturbed/ or existing infrastructure, washout and bare sand, which represented 6%, <1% and <1% respectively. Excluding previously disturbed areas, the vegetation within the survey area varied from good to excellent condition (ENV 2009a, 2009b).

The isolated features in the study area, such as billabong, limestone hill, quartz outcrop and rockpile, are uncommon within the study area and therefore the vegetation within these features is considered to be of local significance.

Table 5.5 – Vegetation Communities Recorded in the Survey Area

Vegetation Map Units	Vegetation Description	Percentage of Study Area (%)	Presence/Absence of Vegetation Map Units in Key Project Component Areas					Vegetation Condition
			Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway	
Mangroves	A high closed *Ceriops tagal* and *Avicennia marina* shrubland.	2	✓	✗	✓	✓	✓	Very Good to Excellent
Dunes A	Scattered *Acacia bivenosa* shrubs over a low open *Crotalaria cunninghamii* shrubland over a **Cenchrus ciliaris* tussock grassland over scattered **Aerva javanica* herbs.	<1	✗	✓	✓	✓	✓	Very Good to Excellent
Dunes B	An *Atalaya hemiglauca*, *Santalum lanceolatum* and *Acacia bivenosa* shrubland over a **Cenchrus ciliaris* tussock grassland.	<1	✓	✓	✓	✓	✓	Good
Dunes C	A low open *Acacia stellaticeps*, *Acacia bivenosa* and *Acacia ampliceps* shrubland over a *Spinifex longifolius* and **Cenchrus ciliaris* open grassland over scattered *Gomphrena canescens* herbs.	<1	✓	✓	✓	✓	✓	Very Good
Samphire A	Scattered *Avicennia marina* shrubs over a low open *Halosarcia halocnemoides* subsp. *tenuis*, *Halosarcia halocnemoides* and *Trianthema turgidifolia* shrubland.	3	✗	✓	✓	✓	✓	Very Good
Samphire B	Scattered *Avicennia marina* shrubs over a low open *Halosarcia halocnemoides*, *Threlkeldia diffusa* and *Halosarcia pterygosperma* subsp. *denticulata* shrubland over a very open *Eragrostis falcata* tussock grassland.	<1	✓	✓	✗	✓	✓	Very Good
Limestone Hill	An *Acacia bivenosa* and *Hakea lorea* subsp. *lorea* shrubland over scattered low *Rhagodia eremaea* and *Scaevola spinescens* shrubs over a scattered *Eriachne obtusa* tussock grasses.	<1	✓	✓	✓	✓	✓	Good to Very Good
Grassland A	*Triodia secunda* and *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✓	Very Good
Grassland B	*Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✓	Good

Table 5.5 – Vegetation Communities Recorded in the Survey Area (continued)

Vegetation Map Units	Vegetation Description	Percentage of Study Area (%)	Presence/Absence of Vegetation Map Units in Key Project Component Areas					Vegetation Condition
			Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway	
Low Hill	An *Acacia tumida* var. *pilbarensis* shrubland over a low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland.	8	✓	✓	✓	✓	✗	Very Good to Excellent
Major Drainage Line A	Scattered low *Eucalyptus victrix* trees over a high open *Melaleuca argentea*, *Acacia ampliceps* and *Acacia trachycarpa* shrubland over scattered *Adriana urticoides* var. *urticoides* and *Pluchea ferdinandi-muelleri* shrubs over an open *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✓	Very Good
Major Drainage Line B	A low open *Eucalyptus victrix* woodland over an *Acacia tumida* var. *pilbarensis* and *Acacia colei* var. *colei* shrubland over a very open *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✗	Very Good
Quartz Outcrop	Small low hills/rock piles with scattered *Acacia col*ei subsp. *colei* and *Acacia inaequilatera* shrubs over scattered herbs over scattered *Triodia* sp. hummock grasses.	<1	✓	✓	✓	✓	✗	Good
Billabong	Scattered low *Eucalyptus victrix* trees over scattered mixed grasses.	<1	✓	✓	✓	✓	✓	Good
Rockpile	Scattered low *Ficus brachypoda*, *Cleorodendrum tomentosum* var. *lanceolatum* and *Carissa lanceolata* trees over scattered herbs.	<1	✓	✓	✓	✓	✓	Good
Drainage A	A low open *Eucalyptus victrix* woodland over a high open *Acacia ampliceps* and *Acacia trachycarpa* shrubland over a low open *Acacia stellaticeps*, *Pluchea ferdinandi-muelleri* and *Corchorus incanus* subsp. *incanus* shrubland over a *Triodia epactia* hummock grassland over an *Aristida holathera* var. *latifolia*, *Eriachne obtusa* and **Cenchrus ciliaris* tussock grassland.	<1	✓	✓	✓	✓	✓	Good to Very Good
Drainage B	A low open *Eucalyptus victrix* woodland over a high open *Acacia ampliceps* shrubland over a low open *Acacia stellaticeps* and *Pluchea ferdinandi-muelleri* shrubland over a closed *Triodia epactia* and *Triodia secunda* hummock grassland over an open *Eriachne obtusa*, *Aristida holathera* var. *latifolia* and **Cenchrus ciliaris* tussock grassland.	<1	✓	✓	✓	✓	✓	Very Good
Sandplain A	Low *Acacia stellaticeps* shrublands over *Triodia epactia* and *Triodia secunda* hummock grasslands/ *Triodia epactia* and *Triodia secunda* hummock grasslands mosaic.	6	✓	✓	✗	✗	✓	Very Good to Excellent
Sandplain B	An open *Acacia colei* var. *colei* shrublands over low *Acacia stellaticeps* shrublands over *Triodia epactia* and *Triodia secunda* hummock grasslands/low *Acacia stellaticeps* shrublands over *Triodia epactia* and *Triodia secunda* hummock grasslands mosaic.	6	✓	✓	✓	✓	✗	Very Good to Excellent

Table 5.5 – Vegetation Communities Recorded in the Survey Area (continued)

Vegetation Map Units	Vegetation Description	Percentage of Study Area (%)	Presence/Absence of Vegetation Map Units in Key Project Component Areas					Vegetation Condition
			Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway	
Sandplain C	A low open *Corymbia flavescens* woodland over an open *Acacia colei* var. *colei* shrubland over a low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland/ low *Acacia stellaticeps* shrublands over *Triodia epactia* and *Triodia secunda* hummock grasslands/ *Triodia epactia* and *Triodia secunda* hummock grasslands mosaic.	7	✓	✓	✓	✗	✗	Very Good to Excellent
Sandplain D	A low *Eucalyptus victrix* woodland over an *Acacia colei* var. *colei* shrubland over a low open *Acacia stellaticeps* and *Pluchea tetranthera* shrubland over a *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✗	✓	Very Good
Sandplain E	A low open *Corymbia flavescens* and *Eucalyptus victrix* woodland over an *Acacia colei* var. *colei* and *Acacia sericophylla* shrubland over a low open *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✓	Excellent
Sandplain F	An open *Acacia tumida* var. *pilbarensis* and *Acacia colei* var. *colei* shrubland over an open *Triodia epactia* hummock grassland.	<1	✓	✓	✓	✓	✓	Good
Sandplain G	A low open *Corymbia flavescens* woodland over an *Acacia colei* var. *colei*, *Carissa lanceolata* and *Acacia sericophylla* shrubland over a *Triodia epactia* hummock grassland over a very open **Cenchrus ciliaris*,[1] *Chrysopogon fallax* and *Eriachne obtusa* tussock grassland.	<1	✓	✓	✓	✓	✓	Excellent
Sandplain H	An *Acacia tumida* var. *pilbarensis* and *Acacia colei* var. *colei* shrubland over a low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland/ low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland mosaic.	5	✓	✓	✓	✓	✓	Very Good to Excellent
Sandplain I	An *Acacia tumida* var. *pilbarensis* shrubland over a low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland/ low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland/ *Triodia epactia* hummock grassland mosaic.	11	✓	✓	✓	✓	✗	Excellent
Sandplain J	Scattered low *Corymbia flavescens* trees over an open *Acacia tumida* var. *pilbarensis* shrubland over a low open *Acacia stellaticeps* shrubland over a *Triodia epactia* and *Triodia secunda* hummock grassland/*Triodia secunda* and *Triodia epactia* hummock grassland mosaic.	<1	✓	✓	✓	✓	✗	Very Good to Excellent
Sandplain K	Scattered low *Owenia reticulata* trees over an *Acacia tumida* var. *pilbarensis* and *Acacia colei* var. *colei* shrubland over a low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland/low *Acacia stellaticeps* shrubland over a *Triodia epactia* hummock grassland mosaic.	6	✓	✓	✓	✓	✗	Excellent

Table 5.5 – Vegetation Communities Recorded in the Survey Area (continued)

Vegetation Map Units	Vegetation Description	Percentage of Study Area (%)	Presence/Absence of Vegetation Map Units in Key Project Component Areas					Vegetation Condition
			Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway	
Sandplain L	A low open *Corymbia zygophylla* woodland over an open *Acacia colei* var. *colei*, *Acacia inaequilatera* and *Acacia ancistrocarpa* shrubland over a low *Acacia sericophylla*, *Acacia stellaticeps*, *Senna artemisioides* aff. subsp. *oligophylla* (thinly sericeous) and *Dodonaea coriacea* shrubland over a very open *Triodia lanigera* and *Triodia epactia* hummock grassland	<1	✓	✓	✓	✓	✗	Excellent
Sandplain M	An open *Acacia ancistrocarpa*, *Acacia tumida* var. *pilbarensis* and *Acacia inaequilatera* shrubland over a *Triodia lanigera* hummock grassland.	<1	✓	✓	✓	✓	✓	Very Good to Excellent
Sandplain N	A low open *Corymbia zygophylla* woodland over an open *Acacia ancistrocarpa, Acacia inaequilatera*, *Acacia tumida* var. *pilbarensis* and *Acacia sericophylla* shrubland over *Acacia stellaticeps* low open shrubland over *Triodia epactia* and *Triodia lanigera* hummock grassland.	13	✓	✓	✓	✓	✗	Excellent
Sandplain O	Scattered low *Eucalyptus victrix* and *Corymbia hamersleyana* trees over an open *Acacia ancistrocarpa*, *Acacia tumida* var. *pilbarensis*, *Acacia inaequilatera* and *Acacia trudgeniana* shrubland over a low open *Acacia stellaticeps* shrubland over a *Triodia epactia* and *Triodia lanigera* hummock grassland.	10	✓	✓	✓	✓	✗	Excellent
Sandplain P	A low open *Eucalyptus victrix*, *Corymbia hamersleyana* and *Corymbia flavescens* woodland over an open *Acacia colei* var. *colei shrubland* over a low open *Acacia stellaticeps* and *Pluchea tetranthera* shrubland over a *Triodia epactia* hummock grassland.	2	✓	✓	✓	✓	✗	Excellent
Sandplain Q	Scattered low *Corymbia flavescens* trees over an open *Acacia ancistrocarpa* and *Acacia bivenosa* shrubland over scattered low *Acacia stellaticeps* shrubs over a *Triodia epactia* and *Triodia lanigera* hummock grassland.	11	✓	✓	✓	✓	✗	Excellent

Notes:
** Vegetation Map Unit present in this area*

One vegetation community recorded by ENV, Major Drainage Line A, contained low numbers of *Melaleuca argentea* (Silver Cadjeput), which is an obligate phreatophyte, meaning it is reliant on groundwater sources for water uptake (ENV 2009a; Halpern, Glick & Maunsell 1999). With a relatively shallow root system, this species is unlikely to occur extensively where the depth to the water table exceeds 2 to 3 m (Muir Environmental 1994, 1995; Weston & Trudgen 1995). Dames and Moore (1984) reported an increase in stress and/or death of this species in relation to drought conditions and increased depth to groundwater.

Eight vegetation communities recorded in the study area: Billabong; Major Drainage Line A; Major Drainage Line B; Drainage Line A; Drainage Line B; and Sandplain D, E and P, contained the tree species *Eucalyptus victrix* (Coolibah) (ENV 2009a). This species is a vadophyte, i.e. a species that primarily relies on water held in the vadose (unsaturated) zone above the water table for water uptake (Jones *et al.* 1990). Whilst not a true phreatophyte, *E. victrix* is likely to exhibit stress if access to groundwater is decreased (Muir Environmental 1995).

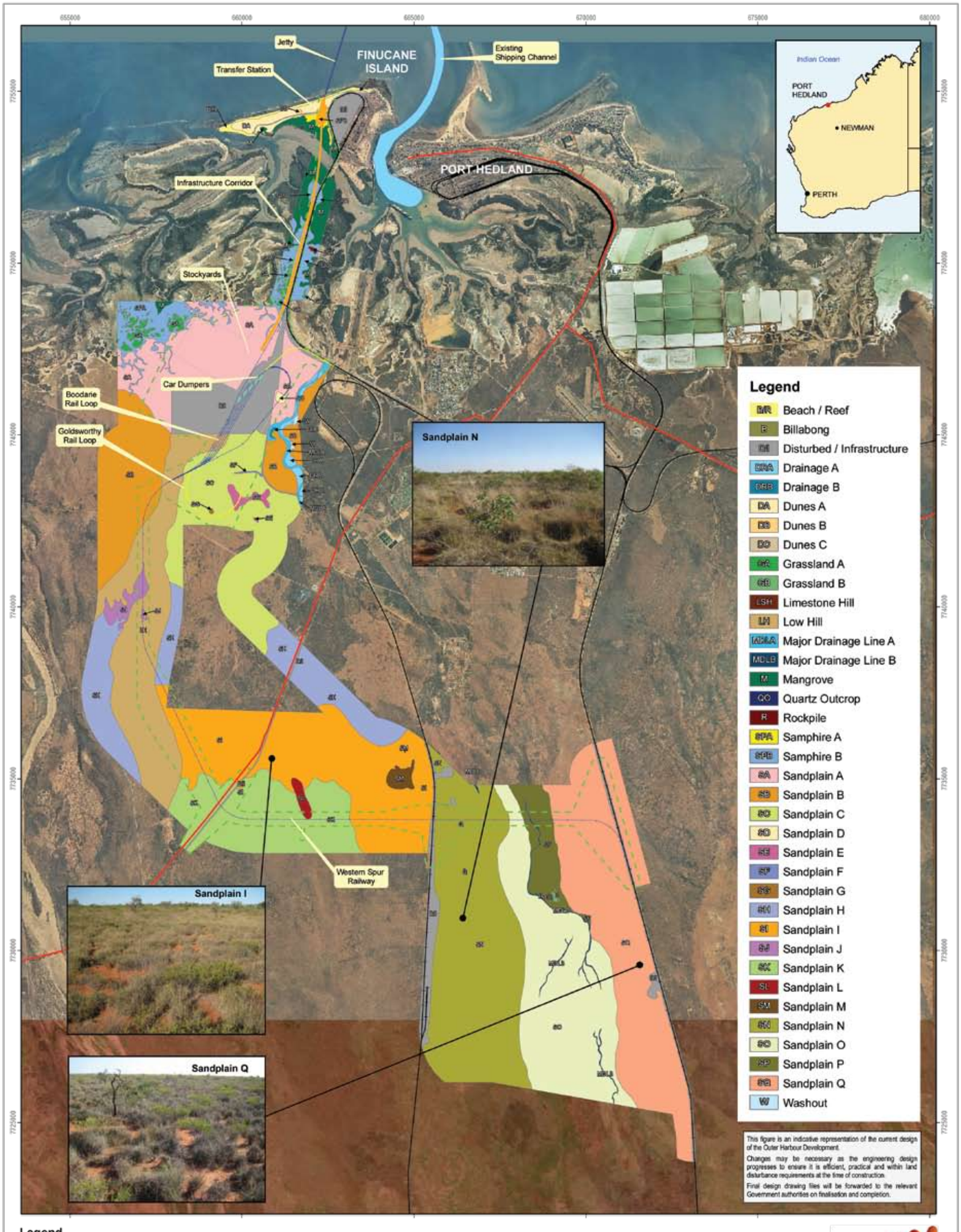


Figure 5.13 Vegetation Communities Recorded in the Survey Area

Flora

A total of 394 taxa (including species, subspecies and variants) were recorded within the study area during surveys conducted in both summer and winter (ENV 2009a, 2009b). Marginally more taxa were recorded in the winter survey than the summer survey, 334 and 250 taxa, respectively. The 394 taxa recorded by ENV consisted of 58 families and 158 genera. The most commonly recorded families were Poaceae (57 taxa), Papilionaceae (45 taxa) and Malvaceae (25 taxa). The most commonly recorded genera were *Acacia* (22 taxa) and *Sida* (12 taxa).

5.5.5 Vegetation of Conservation Significance

One vegetation community, mangroves, was identified as being of conservation significance and is specifically discussed in **Section 6 (Figure 5.13**).

5.5.6 Flora of Conservation Significance

Commonwealth Legislation (Matters of National Environmental Significance)

Threatened Flora

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) focuses on the protection of Matters of National Environmental Significance, with the states and territories having responsibility for matters of state and local significance. Threatened terrestrial flora may be listed under the EPBC Act in any one of the following categories: critically endangered, endangered, vulnerable or conservation dependant.

A search of the DSEWPaC protected matters search tool revealed that no flora species protected under the EPBC Act potentially occur within the terrestrial study area. No flora species protected under the EPBC Act were recorded in the study area during the flora and vegetation surveys (ENV 2009a, 2009b) or Priority Flora survey (ENV 2009c).

Threatened Ecological Communities

No communities listed as Threatened Ecological Communities (TEC) under the EPBC Act were recorded within the terrestrial study area (ENV 2009a, 2009b, 2009e, 2009f). No Threatened Ecological Communities are known to occur in the Roebourne subregion of the Pilbara bioregion.

State Protected Flora

The *Wildlife Conservation Act 1950* (WC Act) provides for the protection of native flora species of conservation significance and identifies them as Declared Rare Flora (DEC 2008b).

To identify if any flora species protected under the WC Act or EP Act potentially occur within the study area, a search was undertaken of the DEC Threatened Flora database, and a review was undertaken of the findings of other flora surveys in the Port Hedland area.

No Declared Rare Flora species protected under the WC Act potentially occur within the study area or in the Port Hedland area. No such species were recorded in the flora and vegetation surveys (ENV 2009a, 2009b) or Priority Flora survey (ENV 2009c).

DEC Priority Lists

Priority Flora

The DEC maintains a 'Priority' list for monitoring flora species, ranging from P1 to P4; with P1 indicating the greatest need for monitoring before the species can be listed as threatened flora (DEC 2008b).

Results from a search of the DEC Threatened Flora database and a review of the findings of other flora surveys in the Port Hedland area, indicated ten species of Priority Flora may potentially occur within the terrestrial study area (**Table 5.6**). Of these species, *Bulbostylis burbidgeae* was previously recorded adjacent to the section of Goldsworthy rail line immediately north of the FMG Railway loop by Biota (2004a). With the exception of *Bulbostylis burbidgeae*, none of the previously recorded Priority Flora from the Port Hedland area is located within the disturbance envelope.

Five Priority Flora species were recorded in the study area during the baseline flora and vegetation surveys and the Priority Flora survey (ENV 2009a, 2009b, 2009c). The total numbers of individual Priority Flora species recorded and their corresponding locations are summarised in **Table 5.7**. Locations and approximate numbers of recorded Priority Flora species are shown in **Figure 5.14**.

Heliotropium muticum, a small perennial herb, was recorded at eight locations during flora and vegetation surveys (ENV 2009a, 2009c) (**Figure 5.14**). This species was recently added to the Priority Flora list and has only five listed locations recorded on FloraBase (WAH 2009).

Tephrosia rosea var. *venulosa,* a shrub, was recorded at nine locations during flora and vegetation surveys (ENV 2009a, 2009b, 2009c). This species was recorded at highest numbers (290 individuals) on Finucane Island (**Figure 5.14**). *Tephrosia rosea* var. *venulosa* was recently added to the Priority Flora list (December 2008), and is considered to have a

Table 5.6 – Priority Flora Species Potentially Occurring in the Study Area

Species	Priority Status	Description[1]	Distribution
Crotalaria spectabilis subsp. *spectabilis*	P1	Annual herb, growing to 2 m high.	Port Hedland
Heliotropium muticum	P1	Ascending to spreading herb, growing to 0.3 m high.	Port Hedland
Ptilotus appendiculatus var. *minor*	P1	Prostrate or ascending perennial, herb or shrub.	Port Hedland, Boodarie.
Tephrosia rosea var. *venulosa*	P1	Erect shrub growing to 1.7 m high. Found within red sands near creeks.	Recorded by ENV (2009d) at Lumsden Point, Port Hedland.
Euphorbia clementii	P2	Erect herb up to 0.6 m high. Found in gravelly hillsides and stony grounds.	Port Hedland area, Yarrie.
Gomphrena pusilla	P2	Slender branching annual herb, up to 0.2 m high.	Dampier Peninsula, Port Hedland.
Pterocaulon sp. *A Kimberley Flora* (B.J. Carter 599)	P2	Compact shrub to 0.5 m high. Found in sandy coastal areas and saline sandy flats.	Broome, Anna Plains. Recorded by ENV (2009d) at Lumsden Point, Port Hedland.
Acacia glaucocaesia	P3	Dense shrub or tree, 1.8 to 6 m high. Found in flood plains with red loam, sandy loam or clay.	Port Hedland, Mardie, Roebourne, De Grey.
Bulbostylis burbidgeae	P3	Tufted annual herb, 0.03 m to 0.25 m high. Found in granite outcrops and cliff bases.	Mount Edgar, Gorge Creek, Abydos-Woodstock. Recorded by Biota (2007) at Utah Point and within FMG Railway line (Biota 2004a).
Gymnanthera cunninghamii	P3	Erect shrub, 1 to 2 m high. Found in sandy soils.	Dampier Archipelago, Boodarie, Eighty Mile Beach. Recorded within both the FMG and Hope Downs railway lines (Biota 2004a; Hope Downs Management Services 2002).

[1] *Source: WAH (2009)*

Table 5.7 – Priority Flora Recorded in the Study Area

Flora Species	Priority Level	No. of Locations Recorded in Survey Area	Approximate Total no. of Individuals identified in Survey Area	Presence/Absence of Flora Species in Key Project Component Areas				
				Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Railway
Heliotropium muticum	P1	8 (3)	17 (12)	✗	✗	✗	✗	✓
Tephrosia rosea var. *venulosa*	P1	9 (5)	535 (531)	✓	✗	✗	✓	✗
Pterocaulon sp. *A Kimberley Flora* (B.J. Carter 599)	P2	2 (1)	2 (1)	✗	✗	✗	✓	✗
Gymnanthera cunninghamii	P3	2 (0)	5 (0)	✗	✗	✗	✗	✗
Goodenia nuda	P4	3 (2)	221 (150)	✗	✗	✓	✓	✓

Notes:
✓ *Flora species present in this area*
✗ *Flora species absent in this area*
( ) No. of locations or individuals identified in the proposed disturbance envelope

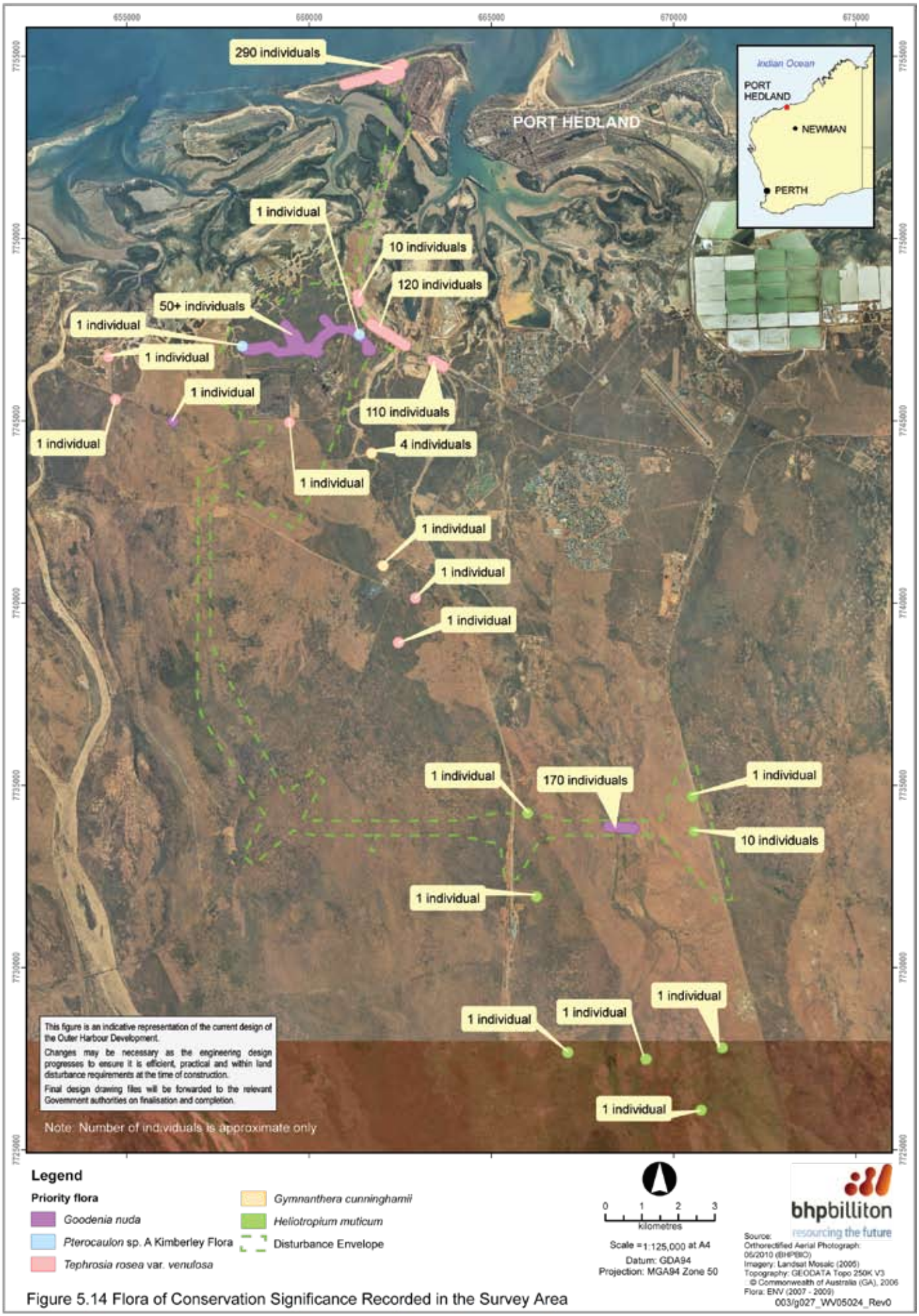


Figure 5.14 Flora of Conservation Significance Recorded in the Survey Area

restricted distribution within the Pilbara region, known only from the Port Hedland and Cape Lambert areas. This species is thought to prefer disturbed areas due to a lack of competition from other species. Outside of the study area, approximately 350 individuals of *Tephrosia rosea* var. *venulosa* have been recorded north of Wedgefield (ENV 2009d), with a further estimated 914 individuals recorded adjacent to various sections of the existing Goldsworthy Railway (ENV 2009b, 2009c).

Pterocaulon sp. *A Kimberley Flora* (B.J. Carter 599), a small shrub, was recorded at two locations during flora and vegetation surveys (ENV 2009a, 2009c). *Pterocaulon* sp. *A Kimberley Flora* is typically recorded in the Kimberley region of Western Australia, and its occurrence within Port Hedland is considered a range extension (i.e. an extension to a species' geographical distribution). A voucher specimen was lodged with the Western Australian Herbarium and subsequently confirmed that the records obtained during the ENV (2009c) survey constitutes a range extension. Two individuals of this species have also been recently recorded to the north of Wedgefield (ENV 2009d).

Goodenia nuda was recorded at three locations during flora and vegetation surveys (ENV 2009a, 2009c) (**Figure 5.14**). *Goodenia nuda* has not previously been recorded in the Port Hedland area, with most historical records of this species located further inland. The presence of this species in this study area is therefore considered a range extension (WAH 2009).

Naturemap lists 42 records of this species, Florabase lists 21 species, with a distribution extending from Well 10 on the Canning Stock Route in the South, between Dampier and Onslow in the North West, and Port Hedland in the North East (records from the ENV 2009 surveys). BHP Billiton Iron Ore's biological database has 99 records for *G. nuda*. This database contains specimen data from the DEC and specimen records from surveys commissioned by BHP Billiton Iron Ore on or adjacent to BHP Billiton Iron Ore tenure. The database has a record for G. nuda near Shay Gap, located approximately 175 km east of the Port Hedland record.

G. nuda was recorded in Low Acacia Shrubland over Triodia Hummock Grassland. This habitat is widespread and common within the Port Hedland region.

Gymnanthera cunninghamii was recorded at two locations during flora and vegetation surveys (ENV 2009a). This species has previously been recorded in the Port Hedland area during the survey for the FMG Railway corridor and Hope Downs Railway corridor (Biota 2001, 2004a, 2004b).

Priority Ecological Communities

A search of the DEC's Threatened Ecological Communities and Priority Ecological Communities database revealed that no Priority Ecological Communities potentially occur within the vicinity of the terrestrial study area. No communities listed as Priority Ecological Communities, as per the DEC Priority list, were recorded in the study area during flora and vegetation surveys (ENV 2009a, 2009b).

5.5.7 Introduced Flora Species

A total of ten introduced species were identified within the terrestrial study area during the baseline surveys (ENV 2009a, 2009b):

- **Aerva javanica* (Kapok Bush);
- **Cenchrus ciliaris* (Buffel Grass);
- **Stylosanthes hamata* (Verno Stylo);
- **Chloris virgata* (Feathertop Rhodes Grass);
- **Citrullus colocynthis* (Bitter Apple or Wild Watermelon);
- **Digitaria ciliaris* (Summer Grass);
- **Merremia dissecta* (Snake Vine);
- **Setaria Verticillata* (Whorled Pigeon Grass);
- **Cucumis melo* subsp. *Agrestis* (Ulcardo Melon); and
- **Portulaca oleracea* (Purslane).

None of the recorded introduced species are 'Declared Plants' listed under the *Agriculture and Related Resources Protection Act 1976* (ARRP Act). Two of the introduced species recorded within the study area, **Aerva javanica* and **Cenchrus ciliaris*, are rated as high risk in terms of potential invasiveness, distribution and environmental impacts by the Environmental Weed Strategy for Western Australia (Department of Conservation and Land Management 1999). These two introduced species were also recorded in historical flora surveys (Mattiske 1994).

5.5.8 Vertebrate Fauna

Relevant Surveys

A two-phase fauna survey of the project area was undertaken by ENV in October 2007 and May 2008, representing summer and winter seasons, respectively (ENV 2009e). These surveys were Level Two surveys as per the EPA Guidance Statement No. 56 (EPA 2004b), and included a habitat assessment, fauna trapping, ornithological censuses, bat acoustic recording and opportunistic fauna searches. ENV

1 An asterix prior to the species name is the typical way to indicate an introduced species

undertook an additional fauna survey in October 2008 that included a portion of the study area adjacent to the existing Goldsworthy Railway (ENV 2009f). This survey was a Level One survey, and included a habitat assessment and opportunistic fauna searches. The area surveyed (the terrestrial study area) is shown in **Figure 5.15**. The results of the research undertaken are detailed in **Appendix B15**.

Previous fauna surveys that have encompassed parts of the study area include:

- the RGP5 Dredge Material Management Area A (Biota 2008); and
- the decommissioned HBI Plant at Boodarie (Mattiske 1994).

The fauna survey undertaken by Mattiske (1994) included habitat assessment, fauna trapping, ornithological censuses and opportunistic searching for fauna. The fauna survey undertaken by Biota (2008) included a habitat assessment and opportunistic fauna searches.

Other fauna surveys undertaken in the vicinity of the Outer Harbour Development include those at Finucane Island (Biota 2007), Port Hedland (Biota 2006b), Lumsden Point (Biota 2009), and the FMG Railway line (Biota 2004b).

Fauna Habitat

Six fauna habitats (excluding areas devoid of native vegetation such as disturbed areas, washout and bare sand) were mapped within the study area during the ENV baseline fauna surveys (ENV 2009e, 2009f). Fauna habitats and disturbed areas identified within the study area are detailed in **Table 5.8** and shown in **Figure 5.15**. Fauna habitats found within intertidal areas, that is, those mapped by ENV as mangroves, tidal flats and samphire, are discussed in greater detail in **Section 6**.

The most prevalent fauna habitat present within the study area was the sandplain habitat, representing 88% of the study area. **Figure 5.15** illustrates the fauna habitat within the area surveyed (ENV 2009e, 2009f).

Local isolated landform features that may provide fauna habitat were also recorded during the fauna surveys (ENV 2009e, 2009f). These features included billabongs (i.e. Cooliarin Pool), quartz outcrops, rockpiles, and limestone hills (**Figure 5.15**). As these features are considered uncommon in the area they are considered to be of local significance. Isolated landform features collectively represent less than 1% of the area surveyed.

Table 5.8 – Fauna Habitats Recorded in the Terrestrial Study Area

Fauna Habitat Map Unit	Description and Characteristics	Percentage of Study Area (%)	Presence/Absence of Fauna Habitat in Key Project Component Areas				
			Transfer Station	Infrastructure Corridor	Stockyards	Rail Loop	Western Spur Rail
Dunal	Low *Acacia stellaticeps* shrublands over **Cenchrus ciliaris* grasslands (north-facing dunes), or open *Crotalaria cunninghamii* shrublands over **Cenchrus ciliaris* grasslands (south-facing dunes).	1	✓				
Riverine	Thick vegetation dominated by *Eucalyptus* species.	1					✓
Mangroves	Stands of *Avicennia marina* on the southern side of Finucane Island and on the mainland surrounding West Creek.	2		✓			
Tidal Flats	Large open bare areas, scattered *Avicennia marina* shrubs and scattered low samphire species.	3		✓	✓		
Samphire	Large open muddy areas with scattered *Avicennia marina* shrubs over a low open *Halosarcia halocnemoides* subsp. *tenuis*, *Halosarcia halocnemoides* and *Trianthema turgidifolia* shrubland.	< 1	✓				
Sandplains	Thick vegetation dominated by *Acacia* species.	88				✓	✓

Limestone hills have a rocky substrate which provides a small array of microhabitats for ground dwelling reptiles. The vegetation structure is more complex than surrounding Sandplain and offers different areas of refuge and foraging for fauna. Rockpiles, limestone hills and quartz outcrops are not considered to be of conservation significance despite being uncommon to the landscape as they are not restricted to the disturbance envelope, fauna are not specifically reliant on these features and they do not support fauna of conservation significance.

Vertebrate Fauna

The ENV fauna surveys recorded a combined total of 199 vertebrate fauna species of the 366 species that may potentially occur in the study area (ENV 2009e, 2009f). Recorded vertebrates included 26 mammal species, 53 reptile species, 7 amphibian species and 106 avifauna species (ENV 2009e, 2009f).

Of the 106 avifauna species recorded, 48 comprised marine affiliated birds (shorebirds and seabirds, and mangrove passerines) which are discussed in **Section 6**. Seasonal differences were evident in avifauna species, with 35% of avifauna recorded in summer only and 8% recorded in winter only. This seasonal difference in avifauna is largely due to the seasonal visitation of migratory shorebirds and seabirds which comprise 20% of the 106 species recorded.

5.5.9 Fauna Habitats of Conservation Significance

The project fauna surveys (ENV 2009e, 2009f) identified four habitats of conservation value:

- Mangroves: Mangrove areas are considered to be of conservation value as they are known to support shorebirds and seabirds, some of which are migratory or marine listed birds under the EPBC Act;
- Tidal Flats: Characterised by large open bare areas, scattered *Avicennia marina* shrubs and scattered low samphire species, this habitat is considered to be of conservation value as it supports shorebirds and seabirds, some of which are migratory or marine listed birds under the EPBC Act;
- Dunal Areas: These areas are considered to be of conservation value, as they may support a unique faunal assemblage which may include the skink *Eremiascincus fasciolatus* (Narrow-banded Sand Swimmer) and shorebirds and seabirds, some of which are migratory or marine listed birds under the EPBC Act; and
- Riverine: These areas are considered to be of conservation value as they serve as important corridors for fauna movement.

Mangroves and tidal flats as fauna habitats are dealt with specifically in **Section 6**.

The billabong (Coolarin Pool) is considered to be a habitat feature of conservation significance as the permanent water associated with it may attract a diverse suite of fauna.

5.5.10 Fauna of Conservation Significance

This section excludes marine affiliated birds and marine affiliated bats (which are covered in **Section 6**).

Commonwealth Legislation (Matters of National Environmental Significance)

The EPBC Act focuses on the protection of Matters of National Environmental Significance, with the states and territories having responsibility for matters of state and local significance. Threatened terrestrial fauna may be listed under the EPBC Act in any one of the following categories: critically endangered, endangered, vulnerable, conservation dependant or migratory. The national List of Migratory Species consists of those species listed under the following Bilateral Agreements and International Conventions:

- Japan-Australia Migratory Bird Agreement (JAMBA);
- China-Australia Migratory Bird Agreement (CAMBA);
- People's Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA); and
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention).

A search of the DSEWPaC protected matters search tool revealed a total of five terrestrial species protected under the EPBC Act that may potentially occur within the study area (ENV 2009e). Of these potentially occurring fauna, one was recorded during the ENV fauna surveys and two are considered likely to occur in the study area (ENV 2009e, 2009f):

- Rainbow Bee-eater (*Merops ornatus*) (Migratory).

  This bird was opportunistically recorded from two sites within the sandplain habitat during the winter and summer surveys (**Figure 5.15**). The Rainbow Bee-eater typically inhabits forests, shrublands and woodlands, usually near water (Simpson & Day 2004). This species nests in small holes excavated in sandy banks or flat sandy surfaces.

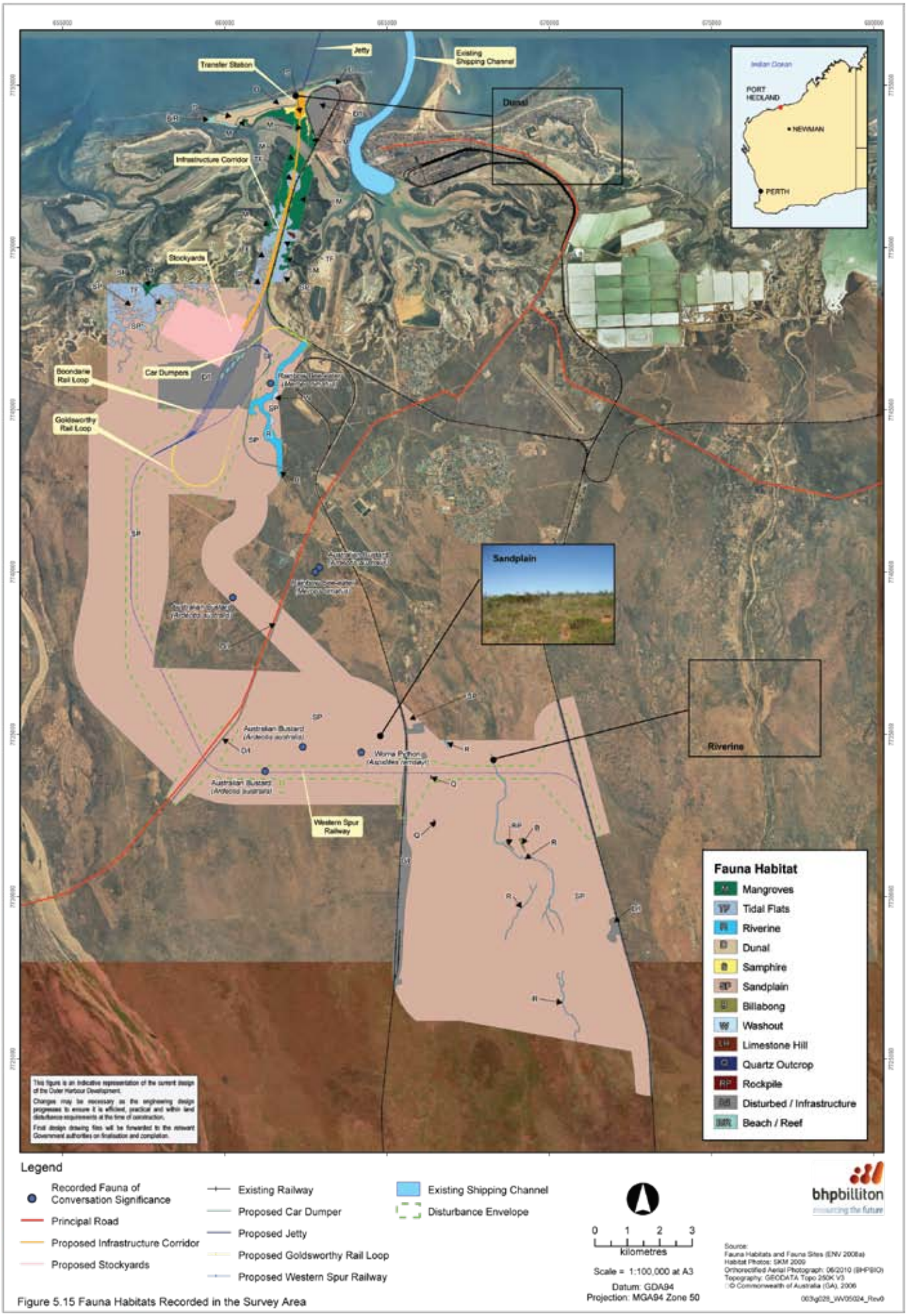


Figure 5.15 Fauna Habitats Recorded in the Survey Area

- Brush-tailed Mulgara (*Dasycercus blythi*) (Vulnerable)

  This mammal was previously known under the taxonomic name of *Dasycercus cristicauda* which is listed as Vulnerable under the EPBC Act. *Dasycercus cristicauda* was recently split into two species, *Daycercus blythi* and *Dasycercus cristicauda* based on morphological and genetic attributes (Woolley 2005, 2006; Van Dyck & Strahan 2008) The name *Dasycercus blythi* is yet to be updated within the EPBC Act (Peacock 2009, pers comm.). This species is typically found in hummock grass plains, sand ridges and mulga shrubland on loamy sand. This species was not recorded during the ENV fauna surveys but was recorded in 2007 approximately 5 km west of South Hedland (Thompson & Thompson 2008). A 2008 record for this species also exists on the DEC's Threatened Fauna Database in the Boodarie area. Therefore, *Dasycercus blythi* is considered likely to occur within the sandplain habitat in the study area.

- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) (Vulnerable)

  Although the Pilbara Leaf-nosed Bat has yet to be recorded in the Port Hedland area, records of the bat have been made on the Roebourne Plain and Abydos Plain, and records are known from several sites in the uplands adjoining the plains (Bullen 2009, pers comm.). This species generally requires deep caves or disused mine shafts in which to roost (Strahan 1995), both of which are absent from the study area and its surrounds. This species is unlikely to be found roosting in the study area but may pass through the study area when foraging, as bats are capable of covering large distances when hunting.

  Populations that are near the limit of species range are considered 'important populations' under the EPBC Act. The coastal location of the project suggests it may encompass portions of 'important populations' of *Rhinonicteris aurantia*, *Merops ornatus* or *Dasycercus blythi*.

  The Night Parrot (*Pezporus occidentalis*) (Endangered) and Northern Quoll (*Dasyurus hallucatus*) (Endangered), are considered unlikely to occur within the study area due to the lack of suitable habitat and historical records for the area.

In addition to the five listed species that were identified as potentially occurring within the study area, an additional 36 species protected under the EPBC Act were identified during the Protected Matters Database search as potentially occurring in the Outer Harbour Development. It is important to note that the Protected Matters Database predicts species that may occur based on bioclimatic modelling and doesn't necessarily reflect records of species within the area. Two of the additional species identified during the search are listed as threatened species. These species are discussed in detail below. The remaining 34 species are listed as Migratory bird species, these are discussed in **Section 6**.

- Northern Quoll (*Dasyurus hallucatus*) (Endangered)

  This species is classified as Endangered under the Commonwealth EPBC Act, and in 2010 it was listed as Schedule 1 – 'Fauna that is rare or is likely to become extinct' under Western Australia's WC Act. The International Union for Conservation of Nature (IUCN) Red List lists it as Endangered.

  The Northern Quoll historically occurred across much of northern Australia. But between 1900 and 1990, a 75% reduction in the Northern Quoll's range has been suggested such that, during this time, the Northern Quoll has been restricted to six major geographical centres: Drummond Range, central Queensland; wet tropics, Northern Queensland; northern Cape York Peninsula; northern and western Top End, Northern Territory; north Kimberley; and Pilbara (Braithwaite and Griffiths1994).

  Recent upgrading and interest in the conservation status of this species is due, in part, to the negative impact of Cane Toads (*Bufo marinus*) in more easterly parts of the Northern Quoll's range, and the threat of Cane Toads in the north and west of the Northern Quoll's range. Cane Toads have had a catastrophic impact on Northern Quoll populations in the Northern Territory and Queensland. Other threats include inappropriate fire regimes and predation.

Northern quolls do not have highly specific habitat requirements; rather they occur in a variety of habitats across their range (Hill & Ward 2010). Den sites occur in a variety of habitats, but in the Pilbara these are generally considered to be rocky areas or breakaways (Biota, 2009b) or granite boulder tors (How *et al*. 1991; ecologia 2010). There are anecdotal records of quolls sheltering and feeding around pastoral stations and active mining and exploration areas, including quarries (ecologia 2010).

The fauna surveys did not record any Northern Quolls, nor was there any indication that the habitats within the project area support dens of this species. At Quarry 1, located to the south of the project area, quolls have been recorded via trapping and from the presence of scats, indicating that if present this species is likely to be recorded via the techniques employed during the fauna surveys. There has been a number of recent anecdotal records of quolls in the Port Hedland townsite, where these animals are likely to be scavenging on food scraps and sheltering in rock armouring or unused buildings.

- Greater Bilby (*Macrotis lagotis*) (Vulnerable)

  The Greater Bilby (Bilby), *Macrotis lagotis*, is listed as Vulnerable under Schedule 1 of the EPBC Act, Vulnerable (specially protected as species threatened with extinction) pursuant to the Western Australian WC Act, and Vulnerable, (C2a), under the IUCN Red List.

  Historically, the Bilby occurred through much of mainland Australia, including most of Western Australia south of the Kimberley region. With the exception of populations in the northern parts of the Northern Territory and Western Australia, Bilbies are now mostly restricted to the drier and least fertile parts of their former range. Within these areas it is generally habitat specific, occurring in three main habitat types:

  - open tussock grassland (both grasses and forbs) growing on uplands and hills;
  - mulga woodland/shrubland (both pure mulga and mixed stands of mulga/ witchetty bush) growing on ridges and rises; and
  - hummock grassland growing on sand plains and dunes, drainage systems, salt lake systems and other alluvial areas (Pavey 2006).

  Decline of Bilbies across their range has generally been attributed to introduced predators and herbivores; which has further been exacerbated by fragmentation of remaining populations (Pavey 2006).

  No Bilbies were recorded during the fauna surveys undertaken for the proposed Outer Harbour Development (**Appendix B15**). This species is generally easy to observe if present due to the prominent and characteristic nature of their burrows. NatureMap has two undated records of Bilbies in the Port Hedland area. It is likely that these are old records, as one occurs in the Port Hedland townsite area, and the other is located approximately 10 km from South Hedland. It is considered highly likely that this species is locally extinct in the Port Hedland area.

State Protected Fauna

The WC Act provides for the protection of native fauna, with species considered as needing special protection listed under various categories. The Wildlife Conservation (Specially Protected Fauna) Notice 2008 (2) lists fauna that are rare, likely to become extinct (Schedule 1) and other 'specially' protected species (Schedule 4) in Western Australia (DEC 2008a).

Results from a search of the DEC Threatened Fauna database and a review of the findings of other fauna surveys in the Port Hedland area, indicated six fauna species protected under the WC Act may potentially occur within the study area (ENV 2009e). Of these potentially occurring fauna, one was recorded during the ENV fauna surveys and four are considered likely to occur in the study area (ENV 2009e, 2009f):

- Brush-tailed Mulgara (*Dasycercus blythi*) (Schedule 1) – discussed above
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) – discussed above
- Woma Python (*Aspidites ramsayi*) (Schedule 4)

  This snake was opportunistically recorded within the sandplain habitat during the winter survey (**Figure 5.15**). The Woma Python typically inhabits spinifex within woodlands, heaths and shrublands (Wilson & Swan 2003). Two records exist in the Port Hedland area for this species on the DEC's Threatened Fauna Database, with the most recent record being for 2001. The Woma Python was also recorded during the Hope Downs rail corridor survey from two locations within 35 km of Port Hedland along the existing BHP Billiton Iron Ore rail access track (Hope Downs Management Services 2002).

- Peregrine Falcon (*Falco peregrinus*) (Schedule 4)

  This bird is considered widespread, although uncommon, throughout Australia. The Peregrine Falcon may utilise the study area as part of its foraging territory.

The Night Parrot (*Pezporus occidentalis*) (Schedule 1) and Northern Quoll (*Dasyurus hallucatus*) (Schedule 1), are considered unlikely to occur within the study area due to the lack of suitable habitat and historical records for the area.

DEC Priority Lists

The DEC maintains a 'Priority' list for monitoring fauna species, ranging from P1 to P5; with P1 indicating the greatest need for monitoring before the species can be listed as threatened fauna (DEC 2008b).

Results from a search of the DEC Threatened Fauna database and a review of the findings of other fauna surveys in the Port Hedland area, indicated ten species of Priority Fauna may potentially occur within the study area (ENV 2009e). Of these potentially occurring fauna, two species were recorded during the ENV fauna surveys and seven species are considered likely to occur in the study area (ENV 2009e, 2009f):

- Woma Python (*Aspidites ramsayi*) (Priority 1) – discussed above.
- Brush-tailed Mulgara (*Dasycercus blythi*) (Priority 4) – discussed above.
- Ghost Bat (*Macroderma gigas*) (Priority 4)

  This bat occurs in a wide variety of habitats, and requires an undisturbed cave, deep fissure or disused mine shaft in which to roost (Strahan 1995). This species is known to occur from the De Grey River through to Onslow, and although it is mainly found in the uplands along the coast, it is also known to use the coastal plains (Bullen 2009, pers. comm.). As no roosting sites were recorded within the study area, the Ghost Bat may only forage temporarily within the study area.
- Australian Bustard (*Ardeotis australis*) (Priority 4)

  This bird was opportunistically recorded from four sites within the sandplain habitat during both summer and winter surveys (**Figure 5.15**). This species is typically widespread. It inhabits woodlands and grasslands, moving widely over large areas (Johnstone & Storr 1998). Two records exist for the Australian Bustard in the Port Hedland area on the DEC's Threatened Fauna Database, with the most recent record being in 2005.
- Blind Snake (*Ramphotyphlops ganei*) (Priority 1)

  There are few previous records of this species, and no records for this species from studies carried out in the vicinity of the study area. Blind snakes are typically very hard to detect and little is known of their habitat requirements, although capture records suggest it prefers rocky or stony soils (Wilson & Swan 2003). As little is known of this species' preferred habitat, it is possible this species may occur.
- Lakeland Downs Mouse (*Leggadina lakedownensis*) (Priority 4)

  This mouse is known to prefer sandplains and clay pans (DEC 2007) with cover of Spinifex and shrubs. The Lakeland Downs Mouse may utilise the sandplain habitat found within the study area (ENV 2009e, 2009f).
- Grey Falcon (*Falco hypoleucos*) (Migratory, Priority 4)

  This bird species inhabits woodland areas in arid zones (Simpson & Day 2004), and may forage in habitats present within the study area.
- Bush Stone-curlew (*Burhinus grallarius*) (Priority 4)

  This bird species is known to inhabit open woodlands with groundcover of small sparse shrubs, grass or litter consisting of twigs.
- Star Finch (*Neochmia ruficauda clarescens*) (Priority 4)

  This bird species occurs in sparsely vegetated grasslands near water (Simpson & Day 2004).

The Western Pebble-mound mouse (*Pseudomys chapmani*) (Priority 4) is considered unlikely to occur within the study area due to a lack of suitable habitat and historical records. The abandoned pebble-mound located within the southern extent of the study area was in a highly degraded state suggesting it had not been active for a number of years (ENV 2009e).

5.5.11 Introduced Fauna

The ENV fauna surveys recorded the following seven introduced fauna species (ENV 2009e, 2009f):

- Domestic House Mouse (*Mus musculus*);
- European Rabbit (*Oryctolagus cuniculus*);
- Wild Dog (*Canis lupus familiaris*);
- Red Fox (*Vulpes vulpes*);
- Feral Cat (*Felis catus*);
- Horse (*Equus caballus*); and
- European Cattle (*Bos Taurus*).

With the exception of the Domestic House Mouse and European Cattle, all of the above are 'Declared Animals' listed under the ARRP Act.

5.5.12 Short-Range Endemic Invertebrate Fauna

Short-range endemic (SRE) fauna are regarded as fauna occupying extremely restricted distributions (defined as an area less than 1,000,000 ha) (Harvey 2002).

Relevant Surveys

A SRE invertebrate fauna survey of the terrestrial study area was undertaken in July 2008 (ENV 2009g; **Appendix B16**). Although this survey was undertaken prior to the publishing of the EPA Guidance Statement No. 20: Sampling of Short-range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (EPA 2009), the methodology used was in general accordance with the guidelines provided in this statement. The SRE invertebrate fauna survey included a SRE fauna habitat assessment and targeted searches for SRE fauna taxa in identified potential SRE fauna habitats.

Short-Range Endemic Invertebrates

Finucane Island was identified as an area likely to promote endemism during the SRE fauna survey. The only potential SRE fauna habitats identified within the disturbance envelope were limestone rocky outcrops, which were located on the northern side of Finucane Island (ENV 2009g; **Appendix B16**). This habitat is also located outside of the disturbance envelope at Boodarie Landing, and is common along the Pilbara coastline (Geological Society of Western Australia 1983).

Limestone rocky outcrops are known to be common habitats along the Pilbara coastline, as evident from the mapped geological units corresponding to limestone rocky outcrops located in the SRE fauna survey (mapped as dune limestone or lime cemented beach conglomerate) (Refer **Figure 5.6**) and occur elsewhere along the Pilbara coast (Geological Society of Western Australia 1983).

Searches of potential SRE fauna habitat in the study area targeted Mygalomorph (Trapdoor) spiders, pseudoscorpions, scorpions, millipedes and terrestrial snails.

The following invertebrates, which are from taxonomic orders known to contain SRE taxa, were recorded by ENV (2009g):

- Gastropods (snails): *Pupoides contrarius*, *Pupoides lepidulus*. These species are considered to have a widespread coastal distribution between Shark Bay and Port Hedland.
- Araneae (spiders): *Aname mainae* (Family Nemesiidae: Trapdoor spiders). This species is considered to have a widespread distribution along the coast of southern Western Australia and the coast of the Midwest. The record at Finucane Island represents a considerable range extension for this species. The absence of records for this species within the Port Hedland area is likely to be due to the lack of previous survey work targeting this taxon.

As these invertebrate species recorded in the study area are all geographically widespread, at the species level they are not considered to be SRE taxa (ENV 2009g).

5.5.13 Subterranean Fauna

Relevant Surveys

A subterranean fauna risk assessment was undertaken by Bennelongia to investigate the potential occurrence of subterranean fauna within the terrestrial study area, and potential risks of subterranean fauna being impacted by the project (**Appendix B17**). The potential occurrence of subterranean fauna in the study area was assessed through a desktop review of known subterranean fauna records, geological and hydrogeological information (Bennelongia 2009).

The two types of subterranean fauna are summarised below.

- Stygofauna are aquatic and live in groundwater (Bennelongia 2009). Athalassic stygofauna (also referred to as 'Pilbara stygofauna') are those which occur in groundwater that is not of direct marine origin (Bayly 1972), whereas marine stygofauna occur in groundwater directly connected to the sea.
- Troglofauna are air-breathing and live in deep subterranean spaces above the water table (Bennelongia 2009).

Findings for stygofauna and troglofauna are summarised below.

Stygofauna

Stygofauna may potentially occur within the study area because suitable geological habitat exists, namely alluvium, silty sand/ clayey sand and dunal limestone, which is present on Finucane Island (Bennelongia 2009). Areas with alluvium, silty sand/ clayey sand and dunal limestone are conventionally viewed as containing sufficiently large interstitial spaces and voids to support subterranean fauna (Gibert *et al*. 1994; Wilkens *et al*. 2000).

Although dunal limestone present on Finucane Island and on the coastal fringe may potentially contain stygofauna habitat, the marine conditions suggest it is likely that marine stygofauna, rather than athalassic stygofauna occur (Bennelongia 2009). Marine stygofauna typically have widespread distributions in comparison to athalassic stygofauna (e.g. Lang 1965; Hartmann-Schroder & Hartmann 1978; Karanovic 2008).

Athalassic stygofauna are considered unlikely to occur within the vicinity of the decommissioned HBI Plant at Boodarie, as groundwater in this area typically has salinities of 10 to 60 mg/L TDS. There are almost no records of athalassic stygofauna in the Pilbara occurring at such high salinities, therefore, it is highly unlikely they occur (Bennelongia 2009). As with Finucane Island, this area may support marine stygofauna which typically have widespread distributions.

Athalassic stygofauna are considered likely to occur within the southern part of the study area, as records exist in the vicinity (within 100 km) of the study area in similar geology. Given that no geological barriers exist and that geographically widespread athalassic stygofauna species have been recorded in surveys in the Turner River Catchment (Halse *et al.* (in prep)), stygofauna in this area are likely to have relatively large ranges covering several river catchments.

Troglofauna

Troglofauna studies are still at an early stage of development in Western Australia. There is no troglofauna trapping data in the public domain from areas closer to Port Hedland than the Ord-Ridley Ranges.

It is known that troglofauna occur in mineralised outcrops and ranges throughout the Pilbara, including coastal areas (Biota 2006c; Subterranean Ecology 2007; Bennelongia 2008) and in calcretes (Edward & Harvey 2008). Troglofauna have very rarely been collected when sampling has extended away from mineralised areas into colluvium, and it has been suggested that sands and gravels are unfavourable habitat in the Pilbara (Biota 2006c). Troglofauna are considered unlikely to occur in the study area given that the geology of the area is dominated by alluvium, silty sand/clayey sand and colluviums (Bennelongia 2009).

Troglofauna are considered unlikely to occur in significant numbers within 5 m below the ground surface because they require high humidity and relatively constant environmental conditions, and at shallow depths they are likely to be outcompeted by surface animals (Bennelongia 2009). Furthermore, in coastal areas where the water table occasionally approaches the surface, any troglofauna are likely to be displaced by rising water. Given the shallow depth to groundwater in the coastal margin of the study area (2 to 3 m), troglofauna are considered unlikely to be present (Bennelongia 2009). Further inland, depth to groundwater is greater (3 to 4 m), hence a depauperate troglofauna community may occur. The alluvial geology of this area is not considered to be high quality troglofauna habitat (Benelongia 2009).

The limestone formations on Finucane Island are unlikely to contain troglofauna as they will be partially inundated with seawater and therefore lacking in air-filled chambers or voids.

5.5.14 Matters of National Environmental Significance

The proposed Outer Harbour Development constitutes a 'controlled action' under the EPBC Act due to the potential significant impacts on the following terrestrial Matters of National Environmental Significance:

- **Listed threatened species and ecological communities**: Two threatened terrestrial fauna species, the Brush-tailed Mulgara (*Dasycercus blythi*) and the Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*), are considered likely to occur in the terrestrial study area (ENV 2009e, 2009f). Threatened fauna species are discussed under Commonwealth Legislation in **Section 5.5.10**. No TECs were recorded within the study area during flora and vegetation surveys (ENV 2009a, 2009b).
- **Migratory species protected under international agreements**: One terrestrial bird recorded during fauna surveys (ENV 2009e, 2009f), the Rainbow Bee-eater (*Merops ornatus*), is listed as Migratory under the EPBC Act. This species is specifically discussed in **Section 5.5.10**. Migratory shorebirds and seabirds are discussed in **Section 6**.

5.6 Summary

The elements of the terrestrial study area's existing terrestrial environment that are considered to be of importance are summarised below.

- **Landforms and Geology:** Areas mapped as being at high to moderate risk of ASS occurring in the top 3 m of the soil profile exist within the coastal periphery of the disturbance envelope. All other aspects of the geology of the disturbance envelope and the associated landforms are not considered unique.
- **Flora and Vegetation:** Five Priority Flora species are located within the study area. One phreatophytic flora species, *Melaleuca argentea*, and one vadophytic flora species, *Eucalyptus victrix* are located within the study area. The terrestrial vegetation communities that occur within the project area are generally well represented in the local area and region and are not considered to be of conservation significance.
- **Fauna**: Fauna habitats of conservation significance exist within the study area such as the Dunal habitat, which may support unique fauna assemblages, and Riverine habitat, which may serve as a fauna movement corridor. These habitats are well represented in the local area. Three terrestrial fauna species of conservation significance occur within the study area, including one fauna species considered to be a Matter of National Environmental Significance. A further four species of conservation significance are likely to occur, including two species considered to be Matters of National Environmental Significance.

Elements of the terrestrial study area's existing terrestrial environment that are considered to be typical of the local Port Hedland area are summarised below.

- **Catchment Hydrology and Groundwater:** Surface water flows and groundwater conditions within the study area are generally representative of those in the general Port Hedland area. The Coastal Catchment and South West Creek Catchment extend well beyond the disturbance envelope. The hydrogeology of the study area is not unique and lacks isolated features.
- **SRE Fauna:** Rocky limestone outcrops found on Finucane Island within the disturbance envelope constitute potential SRE fauna habitat although no SRE fauna were recorded. This habitat is well represented in the local Port Hedland area.
- **Subterranean Fauna:** Stygofauna and troglofauna habitat of the study area is well represented in the local area and the potentially occurring species are unlikely to be restricted in distribution. Marine stygofauna with typically widespread distributions may occur on Finucane Island and the coastal periphery.