3 Existing Natural, Social and Economic Environment

3 EXISTING NATURAL, SOCIAL AND ECONOMIC ENVIRONMENT

3.1 Introduction

This chapter of the draft environmental impact statement (Draft EIS) for the Ichthys Gas Field Development Project (the Project) describes the key physical, biological, social and economic features of the existing environment in the areas to be affected by the Project. A description of the regional environment is also included in order to provide context for the significance of the habitats, resources and socio-economic conditions that currently exist in and around the development areas. The area affected by the Project can be divided into three main components—the offshore, nearshore and onshore development areas—as described in Section 3.1.1 *Development areas*.

A number of scientific surveys and technical studies have been undertaken to characterise the existing environment and to fill gaps in current knowledge. A description of the scoping process for these investigations and a complete list of the studies carried out are provided in Chapter 1 *Introduction*.

3.1.1 Development areas

For the purpose of describing the environment in which the Project will operate, the development area can be divided into three main components:

- the offshore development area, which includes the Ichthys Field in the Browse Basin off the coast of north-western Australia as well as the pipeline route from the field to the mouth of Darwin Harbour
- the nearshore development area, which includes the pipeline route from the mouth of Darwin Harbour south to the waters around Blaydin Point and Middle Arm Peninsula as well as the offshore spoil disposal ground about 15 km north of the entrance to Darwin Harbour
- the onshore development area, which includes the site proposed for the onshore processing plant at Blaydin Point and the onshore pipeline corridor from the shore crossing south of Wickham Point to the Blaydin Point plant.

The major environmental features of each are described below, while a detailed description of the Project infrastructure in each area is provided in Chapter 4 *Project description*.

Offshore development area

The Ichthys Field is located approximately 220 km north-west of the Kimberley coast of Western Australia in the northern Browse Basin at the western edge of the Timor Sea. It is located in Retention Lease WA-37-R, which was granted to INPEX and Total E&P Australia (the Joint Venture Parties) on 21 September 2009 in a portion of petroleum exploration permit area WA-285-P R1 (see Figure 3-1). The offshore waters in the Ichthys Field area are between 235 m and 275 m deep while the waters across the whole permit area are between 100 m and 340 m deep. Browse Island is located 33 km south-east of the field and Echuca Shoal is approximately 55 km to the east. The edge of the continental shelf is located around 20 km west of the field.

The offshore development area also includes the subsea pipeline route, which will extend from the Ichthys Field to the shore-crossing area south of Wickham Point on Middle Arm Peninsula in Darwin Harbour, a distance of around 885 km. Approximately 852 km of the pipeline is in the offshore development area. Most of this route is distant from land, with the exception of the eastern end of the route that curves around Cox Peninsula just before it enters Darwin Harbour. In the eastern third of the route the pipeline will cross the Northern Australia Exercise Area (NAXA), a maritime military zone administered by the Australian Defence Force (ADF).

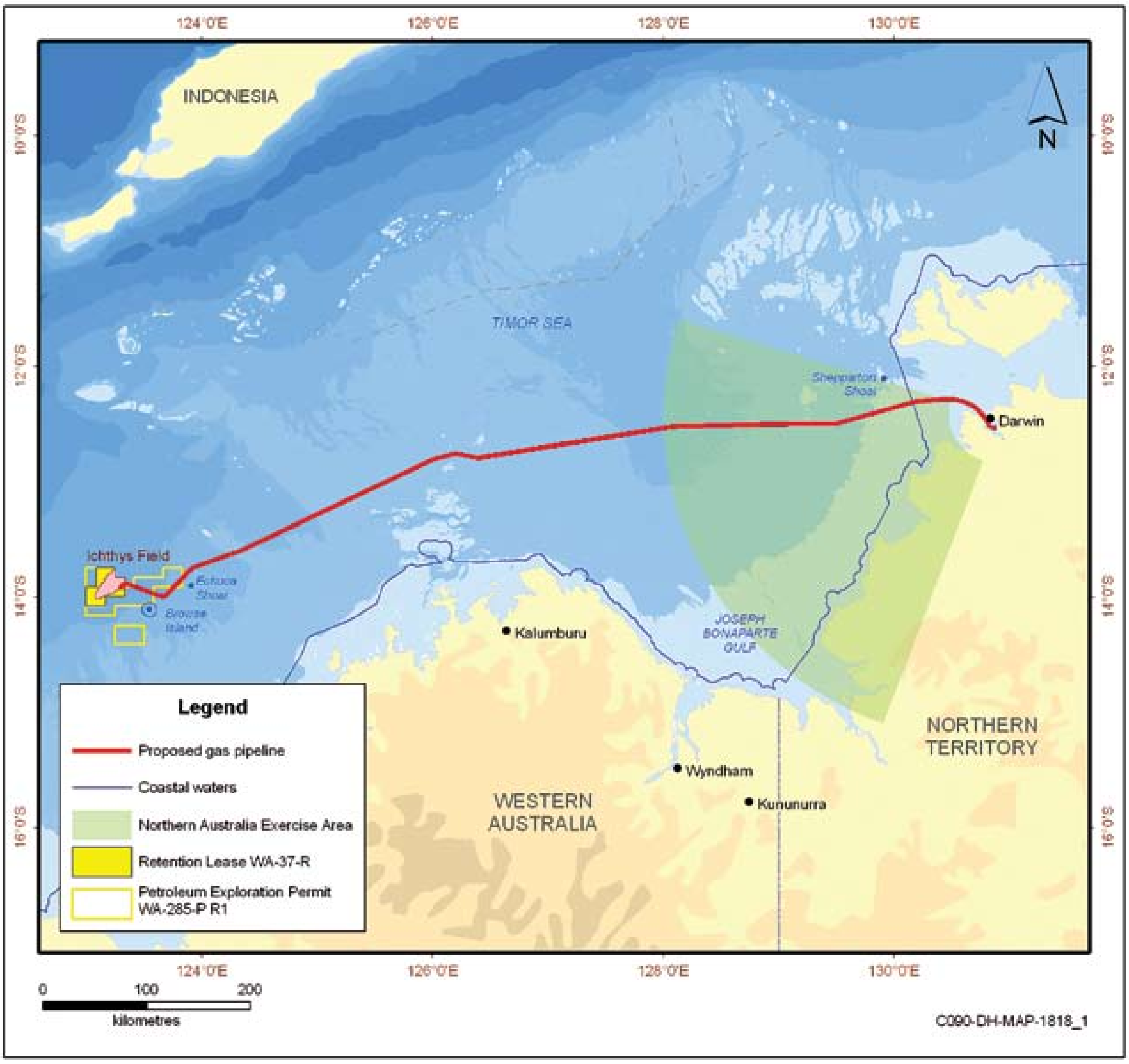


Figure 3-1: The Ichthys Project's offshore development area

Nearshore development area

The nearshore portion of the pipeline route, some 27 km long, extends from the mouth of Darwin Harbour through the Harbour to the low-water mark at the pipeline shore crossing south of Wickham Point on the western shore of Middle Arm Peninsula (see Figure 3-2). The pipeline route for the Project runs adjacent and parallel to the existing Bayu–Undan Gas Pipeline which feeds the Darwin Liquefied Natural Gas plant (Darwin LNG plant) operated by ConocoPhillips. Seabed features near the pipeline route include Kurumba Shoal, Plater Rock and Weed Reef to the west of the alignment. Channel Island is located in Middle Arm, around 1.5 km south-west of the proposed pipeline shore crossing.

The nearshore development area also includes the marine environment below the low-water mark around Blaydin Point. This area is located on the southern bank of East Arm, downstream of the Elizabeth River.

The existing harbour facility of East Arm Wharf lies on the northern side of East Arm. Subsea features of this area include South Shell Island and Old Man Rock. Immediately to the west of Blaydin Point on Middle Arm Peninsula are two narrow tidal creeks known as Lightning Creek and Cossack Creek (known until March 2008 as "Catalina Creeks 1 and 2"), both of which are utilised for recreational fishing.

An offshore site 15–20 km north of the mouth of Darwin Harbour is also considered to be part of the nearshore development area for the purposes of this description. This will be used as a disposal area for material resulting from INPEX's nearshore dredging operations in Darwin Harbour. The site is described in detail in Chapter 4 and in Chapter 7 *Marine impacts and management*.

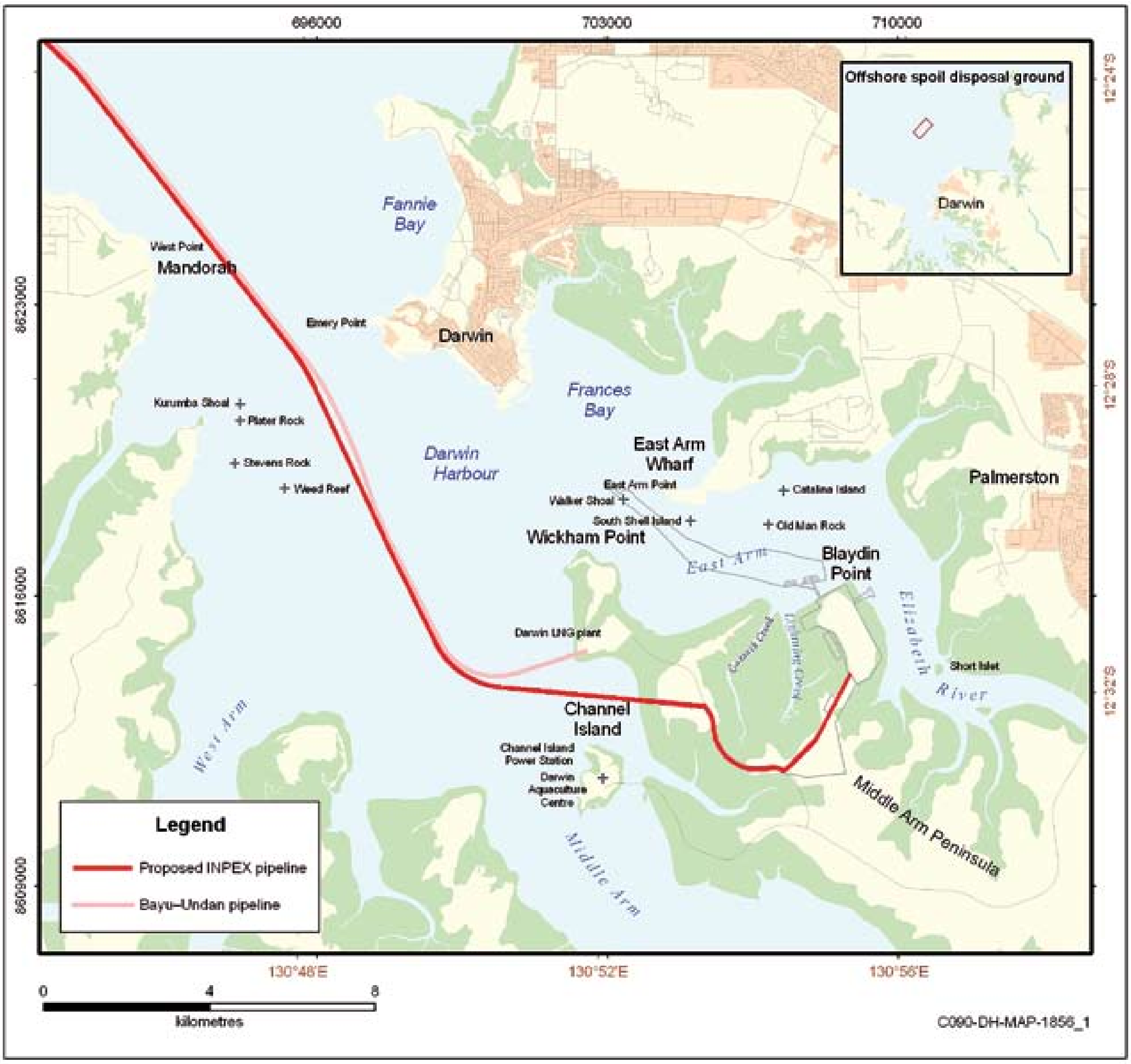


Figure 3-2: The nearshore development area in Darwin Harbour

Onshore development area

The proposed onshore development area will be on Blaydin Point on the northern side of Middle Arm Peninsula above the low-water mark (see Figure 3-3). Blaydin Point is a parcel of land that is linked to the main peninsula by a salt flat except at extreme high tide when the salt flat becomes inundated to a depth of approximately 1 m for periods of up to an hour. Blaydin Point is currently undeveloped. The onshore development area also extends on to the main area of Middle Arm Peninsula and includes the proposed onshore pipeline corridor leading from the western shore of the peninsula across country to Blaydin Point.

Middle Arm Peninsula is currently traversed by a road and services corridor leading to the Darwin LNG plant at Wickham Point as well as to a power station and an aquaculture centre on Channel Island.

3.2 Offshore marine environment

The offshore development area is made up of two parts: the Ichthys Field in Retention Lease WA-37-R in the Browse Basin off the north-western Australian coast and the subsea pipeline corridor from the Ichthys Field to the mouth of Darwin Harbour.

3.2.1 Oceanography and hydrodynamics

Broad-scale oceanography in the north-west Australian offshore area is complex, with the large-scale currents of the Timor and Arafura seas dominated by the Indonesian Throughflow current system (illustrated in Figure 3-4). This current, which is associated with water movement from the Pacific Ocean to the Indian Ocean between the land masses of Indonesia, Australia and Papua New Guinea, is generally strongest during the south-east monsoon from May to September (Qiu, Mao & Kashino 1999).

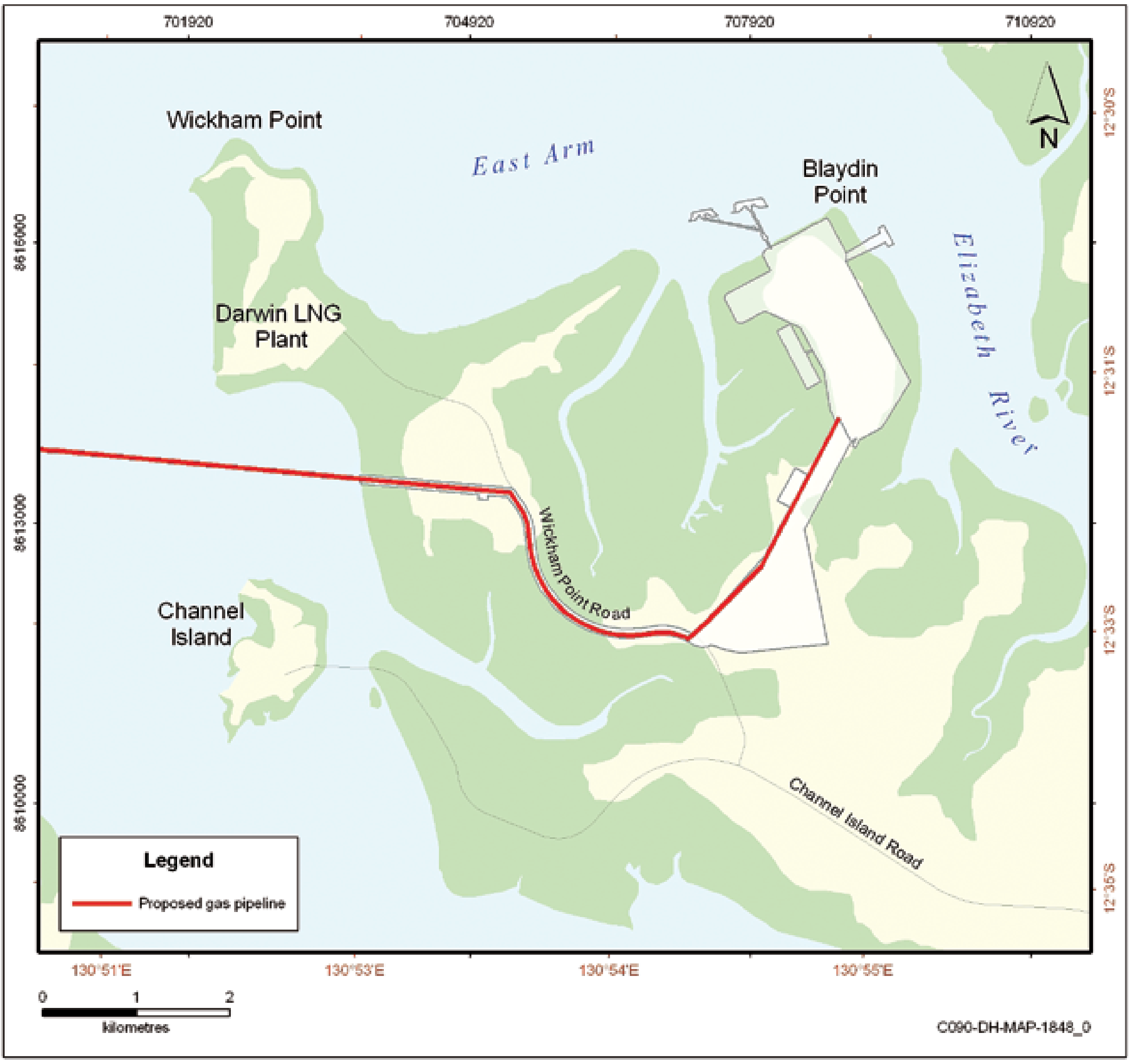


Figure 3-3: The onshore development area

On the outer parts of the continental shelf there are seasonally reversing currents and locally formed water masses characterised by peak south-westward or northward flows and strong meso-scale variability, causing interleaving and mixing of peripheral water masses (Cresswell et al. 1993); Retention Lease WA-37-R is located in this transitional region.

The Browse Basin generally experiences large tides and tidal currents. Mean sea level at the Ichthys Field is about 2.7 m above Lowest Astronomical Tide (LAT), with a spring tidal range of about 5.0 m. Tides are semidiurnal, with two daily high tides and two low tides. Barotropic tidal currents predominantly flow in the cross-shelf direction at the shelf break and in the along-shelf direction when approaching the coast (McLoughlin, Davis & Ward 1988).

This diurnal tide results in relatively short migrations of the thin water-surface layer; longer-term drift is more highly dependent upon the forces of the prevailing winds (see Appendix 7 to this Draft EIS). Meteorological conditions in the offshore development area are described in Section 3.5.1 *Meteorology*.

Southern Ocean swell (also sometimes called Indian Ocean swell) approaches the outer edge of the continental shelf from the south and south-west before refracting over shallower parts of the shelf and approaching the coast from the west, north-west or even north. In the Browse Basin, the swell tends to be higher during winter (with typical significant wave heights about 0.8 m) than in summer (with typical significant wave heights about 0.7 m), because the swell-generating storms move further north in winter. Swell periods are generally of the order of 12–18 s.

In areas of the north-west continental shelf where there is more than 200 km of "fetch" (open water for the wind to blow across), the winter easterly winds

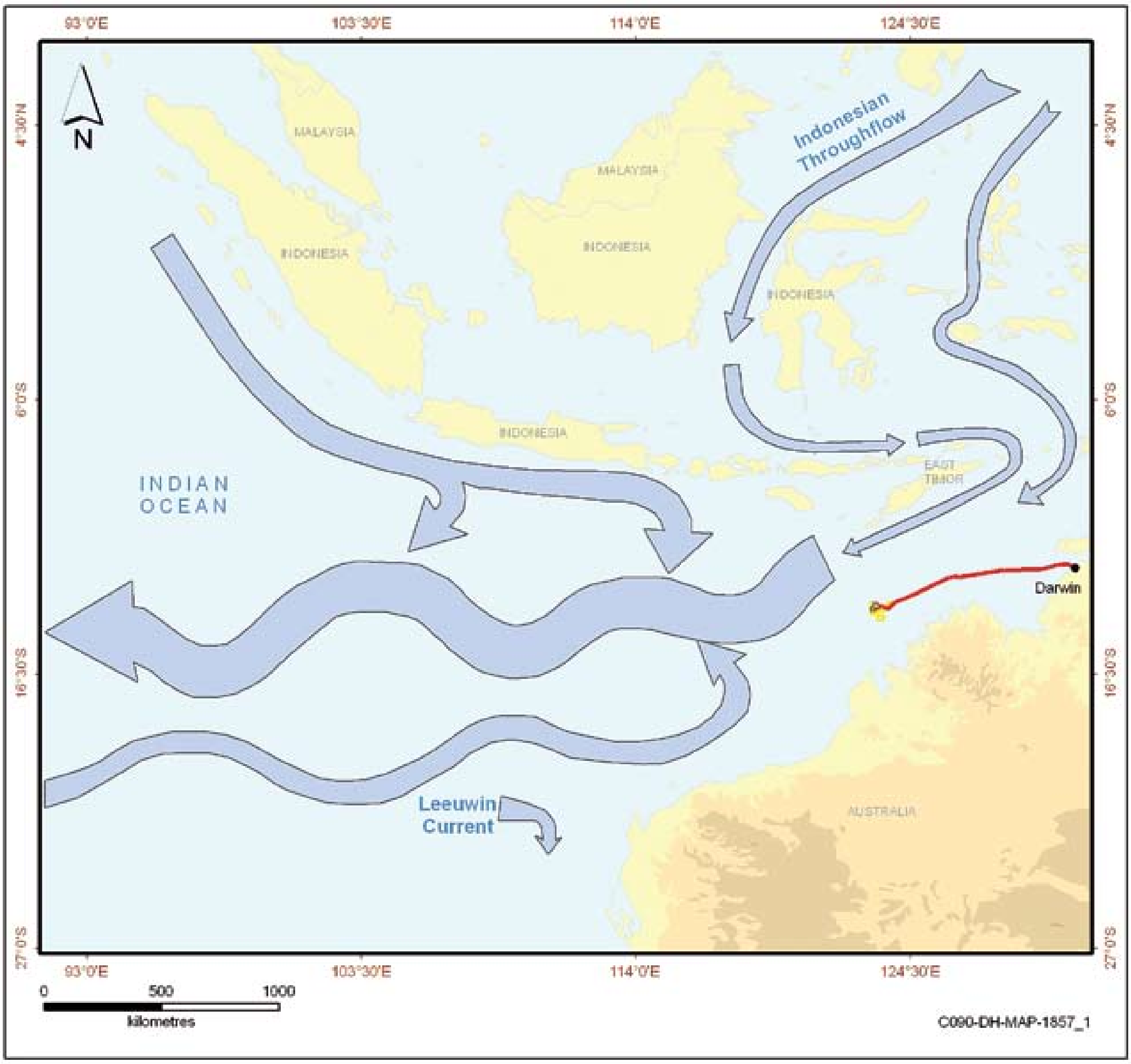


Figure 3-4: Large-scale currents of north-west Australia

generate east-north-easterly swells with a wave period of 6–10 s. In summer, the westerly winds generate west-north-westerly swells with the same period. Such swells may have some influence in the outer-shelf portions of the north-west continental shelf region with significant wave heights[1] of 1–2 m.

Summertime tropical cyclones generate waves propagating radially out from the storm centre. Depending upon the storm size, intensity, relative location and forward speed, tropical cyclones may generate swell with periods of 6–18 s from any direction and with wave heights of 0.5–9.0 m. During severe tropical cyclones, which can generate major short-term fluctuations in current patterns and coastal sea levels (Fandry & Steedman 1994; Hearn & Holloway 1990), current speeds may reach 1.0 m/s and occasionally exceed 2.0 m/s in the near-surface water layer. Such events are likely to have significant impacts on sediment distributions and other aspects of the benthic habitat.

3.2.2 Biogeographical setting

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) has been developed by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA) as a regional framework for planning resource development and biodiversity conservation (DEH 2006a). The IMCRA divides Australian marine areas into two types of bioregion:

- benthic bioregions, provinces and transitions based on the diversity and richness of demersal fish species
- meso-scale (intermediate scale) bioregions, defined by biological and physical information and geographic distance along the coast.

1 "Significant wave height" is calculated as the average of the highest one-third of all of the wave heights during a defined sampling period.

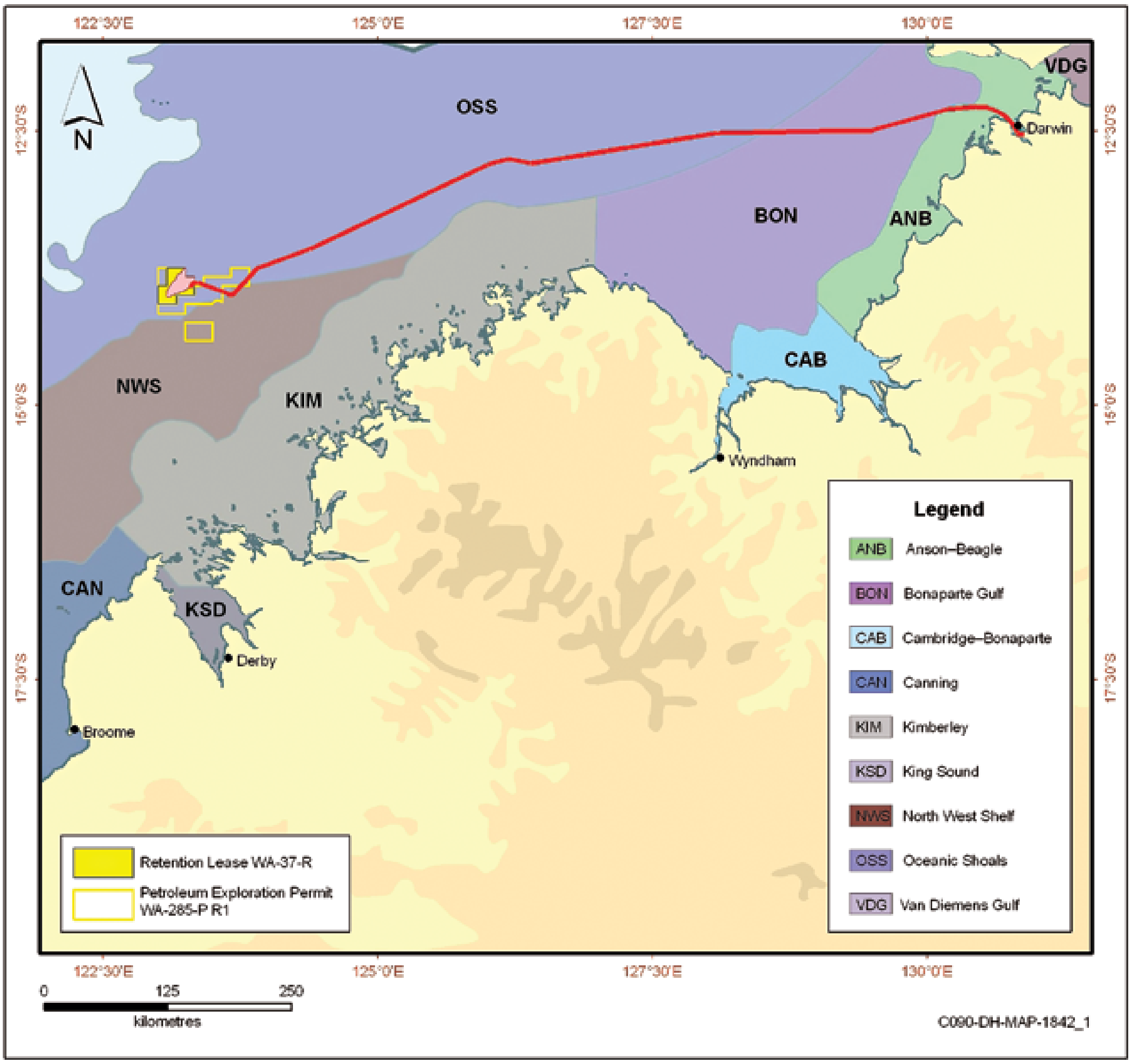


Figure 3-5: Meso-scale bioregions of north-west Australia

Benthic bioregions

The demersal fish provinces are defined by the levels of endemism in the local fish populations: a well-defined demersal fish province has a high occurrence of endemic species and/or a broad geographic coverage, while a weak province has few endemics which are often narrowly distributed. Transitions are areas of species overlap and faunal mixing, where species distributions from the adjacent provinces overlap and few (or no) endemic species occur (Heap et al. 2005).

The offshore development area (in Retention Lease WA-37-R) is located in the Timor Province for demersal fish species, which is considered to be a strong province with a high degree of endemism. The greater part of the proposed pipeline route from the Ichthys Field to Blaydin Point traverses the North-West Transition, a large biogeographic region of mixing and low endemism (Heap et al. 2005).

Meso-scale bioregions

The meso-scale bioregions are defined using biological and physical information, including the distribution of demersal fishes, marine plants and invertebrates; seafloor geomorphology and sediments; and oceanographic data (DEH 2006a).

The offshore development area is located in the Oceanic Shoals Bioregion. A small portion of the permit area is also located in the North West Shelf Bioregion. The proposed subsea pipeline route traverses the Oceanic Shoals, Bonaparte Gulf and Anson–Beagle bioregions from west to east (Figure 3-5). The characteristics of each bioregion are explained in the following sections.

North West Shelf

The IMCRA Technical Group (1998) provides the following information on the North West Shelf Bioregion.

It is located on the outer part of the North West Shelf off the Pilbara and Kimberley coasts, between about the 30-m bathymetric contour and the shelf edge. The southern portion of the North West Shelf is a wide continental platform bordered by the Australian continent on one side and by an abyssal plain on the other. Sediments are predominantly calcareous, with little sediment currently being supplied to this region.

Ocean current speeds in the area are generally high, particularly in deep waters, and are influenced by the poleward-flowing Leeuwin Current. Wave energy is typically moderate but can be extreme during cyclones. Tides are macrotidal with a spring-tide range exceeding 5 m.

The North West Shelf Bioregion has diverse benthic invertebrate communities and a rich pelagic and demersal fish fauna.

Oceanic Shoals

The Oceanic Shoals Bioregion comprises the Australian shelf margin in the easternmost part of the Indian Ocean, the Timor Sea, and the western part of the Arafura Sea, including the continental shelf and the outer part of the continental slope from about Port Hedland in Western Australia to the Cobourg Peninsula in the Northern Territory. It covers the eastern portion of the north-west continental shelf of Australia known as the Sahul Shelf (see also Appendix 4 to this Draft EIS).

In addition to the benthic habitats of the outer shelf and shelf slope, the bioregion is characterised by a chain of biohermic banks, atolls and shoals along the shelf edge rising from the continental slope and by several platform reefs rising from the seafloor of the outer shelf. To the south-west, the Seringapatam, Scott and Rowley Shoals reef systems persist as a disjunct line of near-surface or emergent reefs. Other reefs are emergent and have sandy cays forming small islands, such as Ashmore Reef with its three islets, which support sparse vegetation. None of the islands are inhabited (see Appendix 4).

The extent to which the coral reefs of the Oceanic Shoals Bioregion are interconnected and interrelated in regard to larval recruitment is unknown. The chain of reefs and banks along the shelf edge lies in the path of the south-westerly-flowing current that originates in the Indonesian Throughflow. However, seasonal reversals of flow on the shelf associated with changes in the direction of the prevailing wind have been noted (Cresswell et al. 1993) and larval recruitment may then be supplied from elsewhere. There are also local effects within oceanic currents: in May, during the time of strong shelf-edge flow toward the south-west, there is a reversal of flow on the shelf nearer the coast with currents flowing “almost against the prevailing south-east winds” (Cresswell et al. 1993). This latter effect is likely to be especially important on mid-shelf reefs like that surrounding Browse Island. Interconnectedness is likely to be a complex matter, depending on each reef’s position relative to the seasonal current patterns and the breeding methods and seasonalities of the different species (see Appendix 4).

The plant and animal assemblages of these coral reef systems are typical of oceanic reefs in the Indo-West Pacific region, with some endemism present in the northern sectors. The coral, other invertebrate, and fish faunas are species-rich. The islands support seabird breeding colonies that in some cases are regionally significant. Marine turtles, cetaceans and dugong occur and are also known to breed throughout this bioregion.

The Oceanic Shoals Bioregion is subject to cyclonic activity between December and April. Strong easterly to south-easterly trade winds blow at 15–20 knots almost continuously from May to October. Waters are generally clear and warm (24–30 °C), with moderate wave energy except when the region is influenced by cyclones. Tides are macrotidal to 6 m in the north of the bioregion.

The geology of the bioregion indicates that the continental shelf edge has been rapidly subsiding since the mid-Miocene as a consequence of the collision of the Australian and Asian blocks. The sequence of reef growth in the bioregion is likely to coincide with the postglacial rise in sea level, which stabilised at its present level about 6000 years ago.

Bonaparte Gulf

The Bonaparte Gulf Bioregion consists of the waters in the Bonaparte Gulf deeper than the 30-m isobath and is bordered to the north by the reef complexes of the Oceanic Shoals Bioregion.

This bioregion is characterised by sediments of biogenic gravels and sands, grading to biogenic muds offshore. Biological knowledge of the area is poor, except for trawl bycatch data which indicate that fish assemblages are distinctly different from those of the Arafura Region to the east (IMCRA Technical Group 1998).

The climate of the bioregion is monsoon tropical. Oceanic currents are influenced by the Indonesian Throughflow and the South Equatorial Current. Nearshore currents are generally westerly in the dry season (May to September) and easterly in the wet season (October to March). Waters are generally of low turbidity, with a microtidal range offshore (2–3 m variation) rising to mesotidal inshore (3–4 m variation).

Anson–Beagle

The Anson–Beagle Bioregion comprises the inshore waters of the western Top End coast, including the Beagle Gulf and the southern shores of the Tiwi Islands (Melville Island and Bathurst Island) between the high-water mark and the 30-m isobath—a width of approximately 25 km (IMCRA Technical Group 1998).

The climate in the bioregion is monsoon tropical, with high rainfall in the monsoon season from November to March; cyclones occur with low to moderate frequency. Riverine discharge from wet-season runoff can be significant from the Daly, Finniss and Adelaide rivers. As a result of this discharge, seafloor sediments in Darwin and Bynoe harbours in the east of the bioregion are dominated by coarse sands and gravels of terrigenous origin. In the offshore western part of the bioregion benthic sediments are dominated by biogenic sands and muds.

The major geomorphological features in the Anson–Beagle Bioregion are the ria[2] shorelines in Darwin and Bynoe harbours, the Vernon Islands reef complex on the eastern boundary, and sandy beaches backed by chenier ridge systems and low-cliffed headlands (less than 10 m high) on the western coast. Numerous rocky reefs and shoals are scattered throughout the region. Coralline fringing reefs and patch reefs are sparsely distributed, generally occurring in association with coastal rocky outcrops. The Peron Islands, two extensive sand cays overlying Permian sandstones and siltstones, are located 1 km offshore in the south-west of the bioregion (IMCRA Technical Group 1998).

Other than the extensive fringing mangrove communities of the nearshore area, significant habitat in the Anson–Beagle Bioregion includes wading-bird habitats, turtle feeding and nesting beaches, seagrass beds grazed by dugong, and some hard coral reefs where clear water occurs (IMCRA Technical Group 1998).

Ocean currents exert only a minor influence over this bioregion owing to the breadth of the continental shelf. In the dry season, from May to September, a general south-westerly drift is associated with south-easterly winds, the Indonesian Throughflow and the South Equatorial Current. Wet-season circulation is dominated by north-easterly drift generated by north-westerly monsoonal winds. The Beagle Gulf is dominated by strong internal circulation with little oceanic interaction. Tides range from 6 to 8 m and monsoon conditions can generate turbulent wave action and high turbidity along this coast during the wet season (IMCRA Technical Group 1998).

2 A ria is a drowned river valley, formed as a result of a rise in sea level relative to the land, either by an actual rise in global sea level or by the land sinking.

3.2.3 Seabed and bathymetry

Ichthys Field

The seabed and bathymetry of the Ichthys Field in the area proposed for the development of subsea wells have been characterised through sidescan sonar and multibeam bathymetry surveys undertaken by Fugro Survey Pty Ltd (Fugro) in September and October 2005 and further surveys by Neptune Geomatics in October 2008. These surveys revealed an almost featureless seabed varying in depth between 235 m in the north-east of the area to 270 m depth over the centre and shelving slightly to 260 m to the south-west of the area. All seabed slopes are less than one degree, except where local variations in the seabed bathymetry occur in the north-east and south-west portions where sand waves are present.

The four distinct seabed types in the Ichthys Field may be characterised as follows:

- featureless soft sandy silt
- loose fine-to-medium calcareous sand, generally in the form of sand waves
- loose medium-to-coarse gravelly sand, generally in the form of sand waves
- loose coarse gravelly sand with shell fragments, generally in the form of sand waves.

In general, the seabed sediments grade from soft featureless sandy silts in the north to gravelly sand in the south. Sand forms a cover over the silt, and is generally represented in the form of sand waves. The distribution of seabed type shows some correlation with the water depth—as it becomes deeper to the south the sediments become coarser (Fugro 2005).

Sand-wave crests on the seafloor are aligned in north-east to south-west bands and vary in height and wavelengths. Typical heights are 0.5–1.0 m with wavelengths in the order of 10–25 m. The sand waves are likely to be mobile and overlie the flat-lying sandy silt (Fugro 2005).

During surveys of the field, no obstructions were noted on the seafloor and no features such as boulders, reef pinnacles or outcropping hard layers were identified (Fugro 2005).

The Ichthys Field seabed is suggestive of strong near-seabed currents and mobile sediments that do not favour the development of diverse epibenthic communities. The areas of mud and fine sand on the seabed suggest that it is a depositional area where fine sediments and detritus accumulate. Soft substrates are typical of deep continental shelf seabeds and this habitat is very widely distributed in the deeper parts of the Browse Basin (see Appendix 4).

Pipeline route

The seabed along the pipeline route from the Ichthys Field to Darwin Harbour was characterised through geophysical and geotechnical surveys by Neptune Geomatics between July and November 2008. The survey methods included sidescan sonar and swath bathymetry to provide information on seabed morphology.

The surveys recorded featureless, unconsolidated clay–silt sands along the greater part of the pipeline route (>98%), with the most dominant seabed features being areas of pockmarks and sand waves. Rock subcrop occurred in some areas and exposed outcrop was very rare. Descriptions of sections of the seabed along the pipeline route are provided below. The sections are referred to in terms of their distance (as a "kilometre point" (KP)) from the Ichthys Field, for example KP 0 is located at the Ichthys Field where the survey commenced and KP 860 is near Darwin Harbour where the survey was completed. The seven main sections may be described as follows:

- **KP 0 to KP 97:** The greater part of the gently upward-sloping seabed (around 250–136 m deep) between these points consists of rippled fine-to-coarse sands with an occasional gravelly matrix occurring as a veneer overlying more consolidated cemented calcarenite. Areas of megaripples up to 5 m high are present in this zone.
- **KP 97 to KP 213:** The seabed here is dominated by fine-to-coarse sands with areas of both low-density (<10 per hectare) and high-density (≥10 per hectare) pockmarks between 5 and 10 m in diameter. The seabed in this section slopes gently upwards from a depth of 136 m to 84 m.
- **KP 213 to KP 331:** The seabed is characterised by featureless fine-to-coarse sands with occasional patches of a gravelly matrix and dense (≥10 per hectare) pockmarks.
- **KP 331 to KP 481:** The seabed is characterised by gently sloping, featureless fine-to-coarse sands. Occasional areas of ridged calcarenite subcrop up to 3.4 m high occur between KP 361 and KP 374. A scarp slope with a maximum gradient of 7.2° around KP 379 forms the western side of a 3-km-wide palaeochannel where the water depth reaches nearly 90 m. There are isolated outcrop areas within the palaeochannel.
- **KP 481 to KP 513:** Calcarenite subcrop causes the seafloor to be very rugged in places, with an 11-km-wide palaeochannel between KP 483 and KP 484 that reaches depths of 80–85 m. Small outcrops are present in the shallower waters (at depths of 70–75 m) on either side of the palaeochannel. The subcrop areas are flanked by clay–silt sand, interspersed with sandy gravel patches with a few pockmarks >5 m in diameter.
- **KP 513 to KP 706:** The seabed here is characterised by featureless clay–silt sands dominated by low-density pockmarks (≤10 per hectare) 5–10 m in diameter. Water depths vary from 110 m to 63 m.
- **KP 706 to KP 862:** The seabed is mostly characterised by featureless clay–silt sands with areas of megaripples (KP 799 to KP 804) and sand waves up to 4.9 m high. Water depths vary between 70 m and 11 m (URS 2009a).

In summary, the greater part of the proposed pipeline route (>98%) is made up of featureless, unconsolidated clay–silt sands with the most dominant seabed features being areas of pockmarks and sand waves. The only substantial areas of subcrop are to be found between KP 361 and KP 374 and between KP 482 and KP 513. Exposed outcrop was very rare along the route with only small areas encountered at KP 36, KP 187 and between KP 360 and KP 372 (URS 2009a).

3.2.4 Underwater noise

Ambient noise in the Ichthys Field was measured using a sea-noise logger deployed at a depth of 240 m on the seabed 45 km north-west of Browse Island. The measurements were carried out from September 2006 to August 2008 by the Centre for Marine Science and Technology at Curtin University. The monitoring revealed an average ambient noise level of 90 dB re 1 μPa under low sea states, with inputs of low-frequency energy from the Indian Ocean (McCauley 2009).

Three exploratory drilling programs were conducted by INPEX in the Ichthys Field during the noise-monitoring period. When these operations were under way, low-frequency noise (<1 kHz) was dominated by vessel noise from rig tenders moving slowly, holding station or in dynamically positioned mode. Third-party seismic surveys 136 km to the south-west of the Ichthys Field were also recorded on the noise logger (McCauley 2009).

Biological noise sources recorded in the Ichthys Field included regular fish choruses (one at >1 kHz and another at around 200 Hz), infrequent calls from individual nearby fish, and several whale calls from humpback whales, pygmy blue whales, minke whales and other unidentifiable species (McCauley 2009).

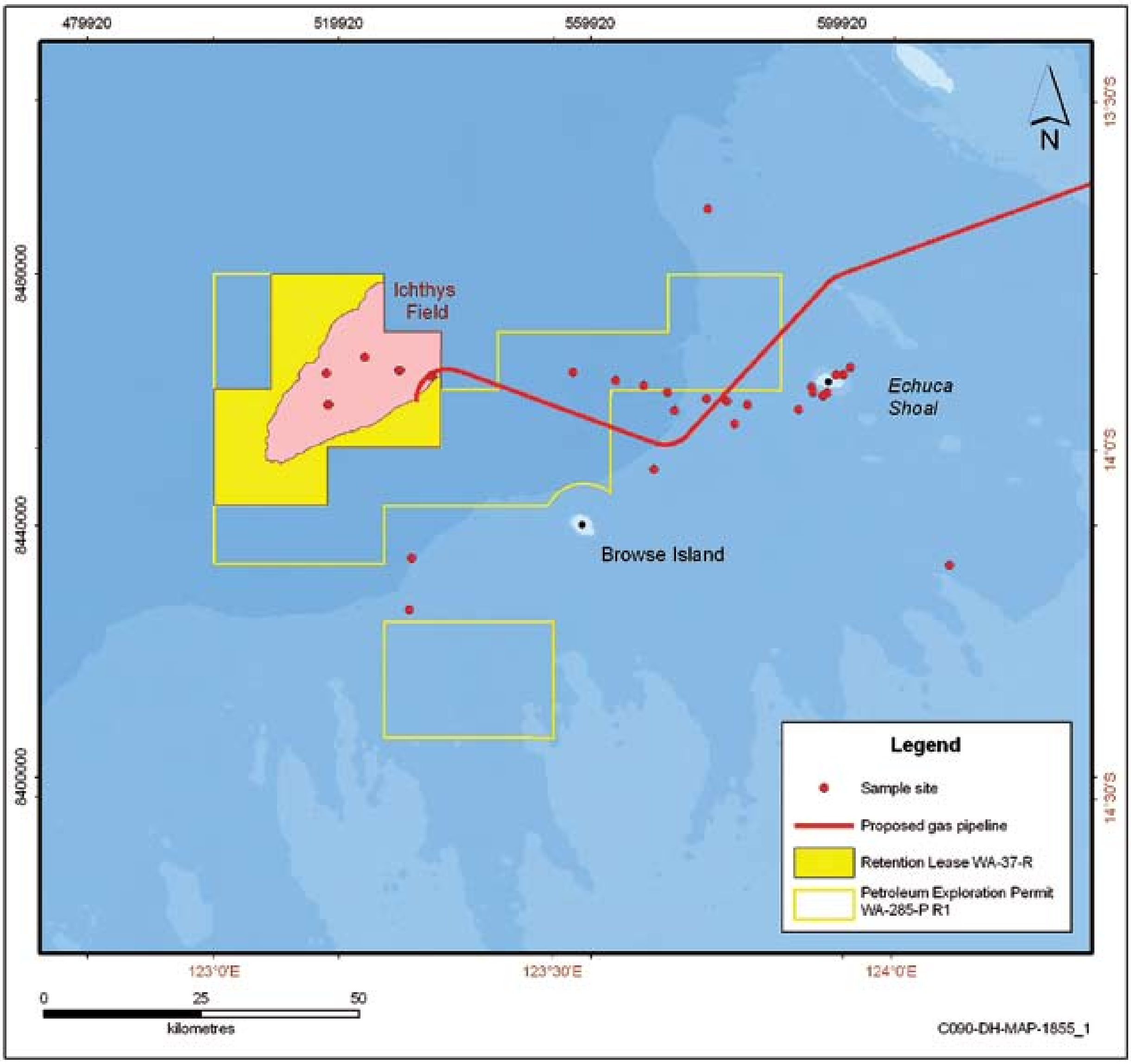


Figure 3-6: Water-quality and marine-sediment sampling sites in the offshore development area

3.2.5 Water quality

Water-quality sampling was conducted by RPS Environmental Pty Ltd in the offshore development area in March 2005 in order to describe the natural conditions of the waters at the Ichthys Field before development commenced and to compare the results with existing applicable guidelines. The most relevant for the marine environment are the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000a) and the Australian guidelines for water-quality monitoring and reporting (ANZECC & ARMCANZ 2000b). These form part of the National Water Quality Management Strategy to which the federal, state and territory governments of Australia are committed.

The water-quality survey investigated a range of physico-chemical properties with sampling to a depth of around 93 m, using in situ instrumentation as well as laboratory analysis. The survey included assessment of the following analytes:

- nutrients: total phosphorus, total nitrogen, ammonium (NH_4^+), orthophosphate (PO_4^{3-}), nitrate (NO_3^-) and nitrite (NO_2^-)
- chlorophyll: chlorophyll-*a*, -*b* and -*c* from phytoplankton samples
- metals: arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, zinc
- hydrocarbons: total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and BTEX (benzene, toluene, ethylbenzene and xylenes)
- radionuclides: radium-226, radium-228, uranium and thorium.

Twenty-seven offshore locations were sampled at the Ichthys Field, Echuca Shoal and their surrounds as shown in Figure 3-6. The results of the study are summarised below and provided in greater detail in Appendix 4.

Additional information on conductivity, temperature and dissolved oxygen in offshore waters was collected by INPEX in July 2008 during exploratory drilling in petroleum exploration permit area WA-344-P, approximately 10 km north-east of the Ichthys Field. These data were acquired using a probe attached to a remotely operated vehicle (ROV) and reached depths of 250 m. Equipment and data analyses were provided by the SERPENT ("Scientific and Environmental ROV Partnership using Existing iNdustrial Technology") project.

Near-seabed temperature and salinity profiles were also obtained along the proposed pipeline route from the Ichthys Field to Darwin Harbour during geophysical and geotechnical surveys conducted by Neptune Geomatics between August and October 2008.

Temperature

Surface-water temperatures recorded in and around the Ichthys Field were consistent across sampling sites at about 30 °C in summer (March) and 26–27 °C in winter (July).

Offshore waters in the region are typified by thermal stratification that varies in strength according to the season (IMCRA Technical Group 1998) (see also Appendix 4). Major thermoclines were encountered at all sites, which may indicate separate subsurface current streams. Depth to the thermocline appeared to increase in winter, with cooler subsurface water encountered at just 30–50 m in summer (March) and at 70–120 m in winter (August). Extreme weather events, such as cyclones and monsoons, may also promote temporary mixing of water layers across the thermocline.

Below the thermocline, water temperatures decreased by roughly 1 °C per 10 m depth (see Appendix 4). Temperatures as low as 12 °C were recorded by INPEX at a depth of 250 m.

Along the pipeline route, water temperatures near the seabed were as low as 15 °C in the deeper waters (150–250 m) at the Ichthys Field. However, in the shallower waters (20–100 m) along the greater part of the pipeline route, the temperatures remained relatively constant at around 25 °C (Neptune Geomatics 2009).

Salinity

Salinity was spatially and temporally consistent at 34–35 ppt across all offshore sampling sites, as expected for locations that are distant from major freshwater discharges. Minor variations in the salinity profile were associated with water layers at depth, particularly in the transitional mixing zone at the thermocline (see Appendix 4).

Seabed salinity levels along the greater part of the proposed pipeline route varied little, with a range of between 34.4 and 34.8 ppt. A slight increase in seabed salinity to 34.9 ppt was recorded in the approaches to Darwin Harbour; this can most likely be attributed to the leaching of terrestrial minerals into the marine environment (Neptune Geomatics 2009).

Dissolved oxygen

Dissolved oxygen concentrations in the offshore development area mirrored water temperatures, with constant levels of 6.0–6.5 ppm recorded at or above the thermocline in both summer and winter. In the cooler waters below the thermocline, however, dissolved oxygen decreased with increasing depth, with levels as low as 4.5–5.0 ppm recorded at a depth of 93 m (see Appendix 4) and 3 ppm at a depth of 250 m (INPEX data, August 2008). This indicates that mixing of the surface and subsurface water layers is limited because of the strong thermal stratification (see Appendix 4).

pH

The average pH of waters in the offshore development area was approximately 8.4, which is slightly higher (more alkaline) than normally encountered in the marine environment and is above the default criteria given in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000a). The reason for this elevated pH level is unknown.

Turbidity and light attenuation

Turbidity was consistent between the profiles, decreasing marginally at all sites with increasing depth. Light attenuation coefficients (LACs) calculated from photosynthetically active radiation (PAR) measurements ranged from 0.026 to 0.043 in October and December 2006, but were higher in June 2007, ranging from 0.048 to 0.109. These were within reported "typical" levels for the region (see Appendix 4).

Nutrients, phytoplankton and total suspended solids

Relatively low concentrations of nutrients and chlorophyll are common in the surface mixed layer on the north-west continental shelf (Condie & Dunn 2006). In the mid- and outer-shelf waters the concentration of nitrate is high below the thermocline and the phytoplankton biomass tends to be concentrated at this depth and in the benthic mixed layer (see Appendix 4).

The median concentration of many forms of nutrients in the offshore development area approached or exceeded guidelines for slightly disturbed tropical ecosystems in northern Australia, particularly with increasing water depth (ANZECC & ARMCANZ 2000a). This trend has also been revealed in previous studies near Scott Reef and Browse Island, and in the Pilbara region of Western Australia. The source of these nutrients has not been determined—they may be transported from distant deeper sources via upwelling currents (this is known to occur elsewhere on Australia's north-west continental shelf) or they may be derived from the local seabed sediments (see Appendix 4).

Chlorophyll-*a* concentrations were low throughout the water-column profile but were similar to concentrations reported previously for the north-west continental shelf. This low concentration indicates a lack of enhanced production and probably reflects the trapping of nutrient-rich waters below the thermocline. However, this effect may also be attributable to the greater dispersion of phytoplankton during winter (when sampling was undertaken) or may suggest that the greater part of the phytoplankton lies well beneath the surface at the base of the thermocline or in the mixed layer near the seafloor where high nitrate levels exist (see Appendix 4).

Phytoplankton surveys conducted at the Ichthys Field recorded densities of 87–610 cells per 50 L (average density 249 cells per 50 L) (Dalcon Environmental 2008). These plankton densities are considered to be very sparse and are indicative of offshore waters where no significant nutrient sources exist. The most common class recorded from the samples was the Prasinophyceae (68%), followed by the Bacillariophyceae (30%), the Dinophyceae (1%) and the Cryptophyceae (<1%), all of which are common throughout the region.

Petroleum hydrocarbons

No traces of petroleum hydrocarbons were detected during offshore water-quality sampling.

Radionuclides

Water-column sampling for radionuclides in the offshore development area indicated activity concentrations of radium-226 from below "lower limits of reporting" (LLR) to 0.034 (±0.012) Bq/L, and of radium-228 from below LLR to 0.167 (±0.128) Bq/L. With the exception of one mid-depth sample, all samples returned gross alpha-particle and gross beta-particle radiation levels below the Australian Drinking Water Guidelines (ADWG) screening criterion of 0.5 Bq/L provided by the National Health and Medical Research Council (NHMRC) and the Natural Resource Management Ministerial Council (NRMMC) (NHMRC & NRMMC 2004).

Metals

Total metal concentrations in offshore waters were below the 99% species protection level for marine waters (ANZECC & ARMCANZ 2000a), with the exception of zinc and cobalt at one site each. The reason for these two slightly elevated readings is unknown.

Ultra-trace-level analysis methods were used to assess metal concentrations in surface waters because ANZECC and ARMCANZ (2000a) guideline trigger values at the 99% species protection level are lower than the limits of standard laboratory methods. Mercury was the only metal not detected above the LLR, while cobalt was marginally above the LLR at only one site. Concentrations of arsenic, nickel, chromium and zinc were consistent across all sites, but the concentrations of cadmium, copper and lead showed greater variability (see Appendix 4).

3.2.6 Marine sediments

Ichthys Field and offshore areas

Sampling of marine sediments in the offshore development area was conducted by RPS Environmental in September 2005 and May 2007 at 10 sites. The results of these surveys are described briefly below and are provided in detail in Appendix 4. The sampling sites are shown in Figure 3-6.

Physical

Background data on marine sediments in the region are scanty because of the remoteness of the location and the fact that there has been minimal exploration and development activity there by the oil & gas industry. The seabed in offshore locations on the continental shelf is known to consist of generally flat, relatively featureless plains characterised by soft sandy-silt marine sediments that are easily resuspended. Similarly, the substrate of the Scott Reef – Rowley Shoals Platform, located immediately south-west of the Ichthys Field in depths of 200–600 m, is considered to be a depositional area with predominantly fine and muddy sediments.

The composition of sediments varied across the offshore development area, with the most variation occurring in the vicinity of the Echuca Shoal close to the eastern boundary of the permit area. In this area sediments consisted mainly of calcareous shell grit and coral debris along with varying minor proportions of silts and fine-to-medium sands. In general, the proportion of silts, clays and fine sands increased rapidly with increasing distance from the shoal (see Appendix 4).

Chemical

No petroleum hydrocarbons were detected in sediment samples: all concentrations of alkanes were below LLR. Concentrations of metals were consistent across all samples and were well below "ISQG-Low" ("interim sediment quality guideline – low") trigger levels (ANZECC & ARMCANZ 2000a).

Radium-226 was detected at one site in the offshore development area, but all other samples were below LLR for each radium isotope. The concentration of uranium and thorium was consistent across all sites.

The sediment samples were assessed for total nitrogen, total phosphorus and total organic carbon. All nutrient concentrations were low, with total organic carbon consistently below LLR (see Appendix 4).

Pipeline route

Seabed sediments along the pipeline route were assessed during a geophysical survey conducted by Neptune Geomatics in 2008. Sampling was carried out using drop-core and piston-core sampling at 110 locations along the pipeline route, at approximately 10-km intervals.

In general, the seabed sediments along the pipeline route can be allocated to one of four types:

- very soft to stiff sandy mud
- very loose to dense muddy silty sand
- fine to coarse (occasionally gravelly) sand overlying a crust of variably cemented sediments
- consolidated bedded muds, silts, and sands intersected by a series of palaeochannels (Neptune Geomatics 2009).

Along the pipeline route from the Ichthys Field (KP 0) to Darwin Harbour (KP 860), the shallow geology can be categorised into three depositional settings and sedimentary classifications:

- **KP 0 to KP 235:** This section is within the Browse Basin and is characterised by a low-energy marine depositional environment, with surface sediments that are very loose and very soft to soft. These overlie horizontal interbedded muds, silts and sands, and a prominent, stiff, sandy mud unit at depth.
- **KP 235 to KP 391:** This section traverses the Yampi Shelf and Londonderry Rise and is characterised by a moderate- to high-energy marine depositional environment with very loose to loose sands and very soft to soft sandy mud surface sediments. These overlie consolidated massive to bedded sands.
- **KP 391 to KP 859:** This section traverses the Joseph Bonaparte Gulf and the Petrel Sub-basin. It is a high-energy fluvial depositional environment consisting of very loose to loose sands and very soft to soft sandy mud surface sediments overlying well to poorly bedded discontinuous beds of muds, silts and sands. This sequence of sediments is frequently intersected by a series of palaeochannels infilled with cross-bedded, poorly sorted sediments (Neptune Geomatics 2009).

3.2.7 Marine benthic habitats and communities

The benthic communities at the Ichthys Field were characterised by RPS Environmental in 2007 using sidescan sonar and bathymetric surveys, ROV surveys and sampling of infauna. Intertidal and subtidal habitats at Browse Island (the closest island to the offshore development area) and subtidal habitats at Echuca Shoal (the closest subtidal shoal to the development area) were also surveyed. Study methods included drop-camera surveys of subtidal habitats, intertidal transect surveys, and sampling of corals and fish. The results of this survey are summarised below while the more detailed results are provided in Appendix 4.

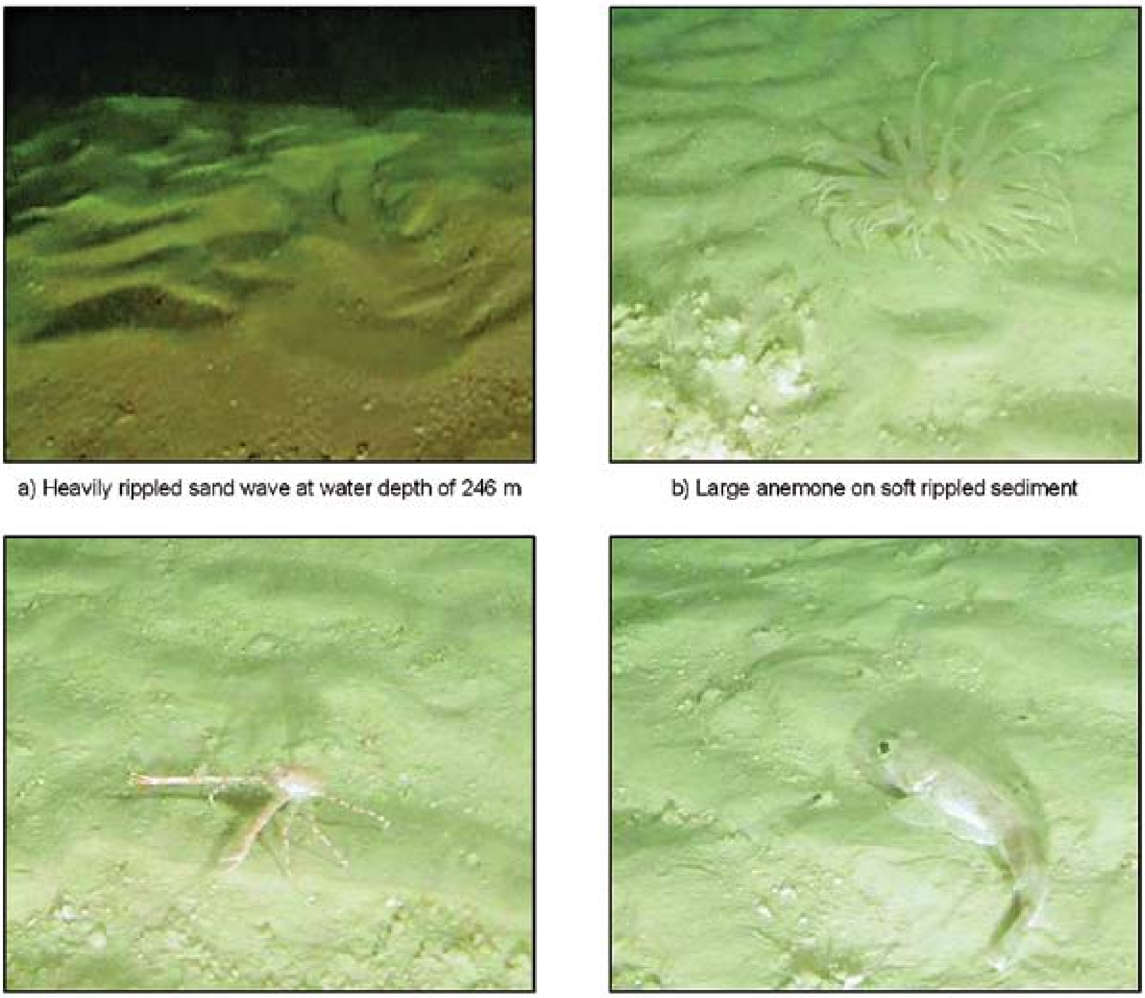
Ichthys Field

Investigations in the central portion of the petroleum exploration permit area WA-285-P R1 were undertaken in water depths of around 250 m. They recorded bare substrates with heavily rippled sand waves approximately 10 m apart (Figure 3-7). Very few epibenthic organisms were observed and the appearance of the seabed was suggestive of very strong currents and mobile sediments that do not favour the development of diverse epibenthic communities (see Appendix 4).

In the south-eastern portion of the permit area, the seabed was described as pavement reef with sand veneer, including low-cover (<40%) filter-feeding communities with sponges, gorgonians (sea whips and sea fans), soft corals, hydroids, bryozoans (lace corals), fan worms and other polychaetes. This area is around 10 km north of Browse Island, with water depths of approximately 190–220 m.

The seabed at the Ichthys Field is well below the photic zone and consequently no benthic macrophytes can be expected in this area.

The infauna in offshore marine sediments was sampled in September 2005 (when 117 species were recorded) and again in May 2007 (when 94 species were recorded).



a) Heavily rippled sand wave at water depth of 246 m

b) Large anemone on soft rippled sediment

c) A galatheid crab

d) Small olive-tailed flathead (*Rogadius asper*)

C090-DH-SKH-5656_0

Figure 3-7: The Ichthys Field seabed with a sample of its animals

The infauna assemblages were dominated by polychaete worms and crustaceans which contributed around 70% of the animal species in both sampling exercises. The polychaetes consisted of tube-dwelling deposit feeders and surface deposit feeders. The crustacean assemblage was made up of small shrimplike species.

Species richness and abundance decreased with increasing distance from land and with increasing water depth. The composition of the infauna also appeared to be related to sediment particle size, the sites with high sand fractions having a suite of species different from those found at sites dominated by clay or silt sediments, regardless of the distances between the sites and differences in water depth. These observations were consistent with those noted in previous studies.

The low dissolved-oxygen levels at depth in the offshore development area (see Section 3.2.5 *Water quality*) are likely to limit the diversity and composition of infauna assemblages (see Appendix 4).

Browse Island

Browse Island is an isolated sandy cay surrounded by an intertidal reef platform and shallow fringing reef. The reef complex is an outer-shelf, biohermic structure rising from a depth of approximately 200 m. It is a flat-topped, oval-shaped platform reef with a diameter of 2.2 km at its widest point. Rocky-shore habitat around the island is represented only by exposed beach rock and there are no intertidal sandflats. The reef platform is high and conspicuously barren in many places. The reef crest and seaward ramp habitats around the edge of the reef support moderately rich assemblages of molluscs, while the shallow subtidal zone is narrow and supports relatively small areas of well-developed coral assemblages (see Appendix 4).

Intertidal habitats around Browse Island include the following:

- a sandy beach zone of coarse coral sand. Turtles are known to nest here, but the sand does not provide suitable habitat for invertebrates such as bivalves and gastropods
- beach rock, especially on the southern and western sides. A modest invertebrate fauna was recorded in the lower parts of this habitat, including barnacles and marine snails
- a lagoon with sand and coral rubble substrates, supporting macroalgae and live corals such as *Acropora* spp. and *Porites* spp. Very few other invertebrate animals, such as burrowing bivalves or gastropods, were recorded in this habitat
- a reef platform, which is widest on the southern and western sides. Most of this habitat is exposed at low tide and contains areas of sand and coral rubble. There is some exposed limestone supporting sparse algal turf and there are many barren shallow pools
- the reef crest. This supported the highest diversity of molluscs of all the habitats, of both surface-dwelling and cryptic species. Hard corals of the family Faviidae (such as *Goniastrea* spp.) were also recorded in this habitat
- a seaward ramp, which is wave-swept except during very low tides and has a ragged edge. Plant and animal life includes some algal cover and live corals of species similar to those found in the lagoon and on the reef platform and reef crest (see Appendix 4).

The width of the shallow subtidal zone (<20 m depth) outside the reef at Browse Island ranges from 50 m to 200 m. The greater part of the oceanic swell appears to impact the island from a north to south-west direction, leaving mainly bare limestone. The most diverse coral communities were recorded in raised coral reefs in shallower areas around the island, including some large monospecific thickets of branching *Hydnophora rigida* along with tabular *Acropora* and occasional large *Porites* colonies.

The benthic habitats and biotic assemblages at Browse Island are characteristic of coral platform reefs throughout the Indo-West Pacific region. The small area of intertidal habitat at Browse Island, the elevation of the reef platform, and the constrained shallow subtidal area appear to have limited the development of benthic communities, including coral communities, around the island.

Coral diversity was greater on the reef faces and in the shallow lagoons, but these areas are of very limited extent. The molluscan assemblage was limited and strongly dominated by widespread Indo-West Pacific species. Macrophytes such as seagrasses and macroalgae of the genus *Sargassum* do not appear to occur in intertidal or shallow subtidal areas at Browse Island (see Appendix 4).

Echuca Shoal

Benthic surveys at Echuca Shoal encountered substantial areas of hard bottom substrate with its associated epibenthic fauna. Seabed substrates are dominated by coral rubble, reflecting impacts from high-energy waves and swells generated during tropical storms and cyclones.

The shallow shoal areas are dominated by a flat “reef” platform comprising hard corals (particularly large *Porites* and *Platygyra* colonies), feather stars (class Crinoidea), sea whips and other soft corals (including species of *Junceella*, *Sarcophyton* and *Dendronephthya* and black corals of the genus *Antipathes*). The largest features observed in the shallows were the remains of large coral colonies, which were heavily eroded and covered in encrusting and boring sponges. All the taxa recorded are common in tropical Western Australian reef habitats.

With increasing depth (25–80 m), soft corals (particularly of the genus *Dendronephthya*) and sponges (particularly barrel sponges of the genus *Xestospongia*) become increasingly dominant, with limited hard-coral abundance because of decreasing light levels. At greater depths the density of epibenthic fauna decreases dramatically, with sea whips and sea fans dominant (particularly between 80 and 100 m). Below the drop-off of the slope at the edge of Echuca Shoal (at depths of 180–200 m), bare sand is the dominant substratum, with sponges, feather stars and occasional echinoderms, sea whips and sea fans present (see Appendix 4).

Pipeline route

Benthic habitats at 18 sites along the pipeline route (Figure 3-8) were characterised by drop-camera surveys conducted by URS in December 2008 (see Appendix 4). Survey sites were selected based on the results of geophysical and geotechnical surveys of the route (see Section 3.2.3 *Seabed and bathymetry*), which identified areas of hard substrate along the route that could be of ecological interest.

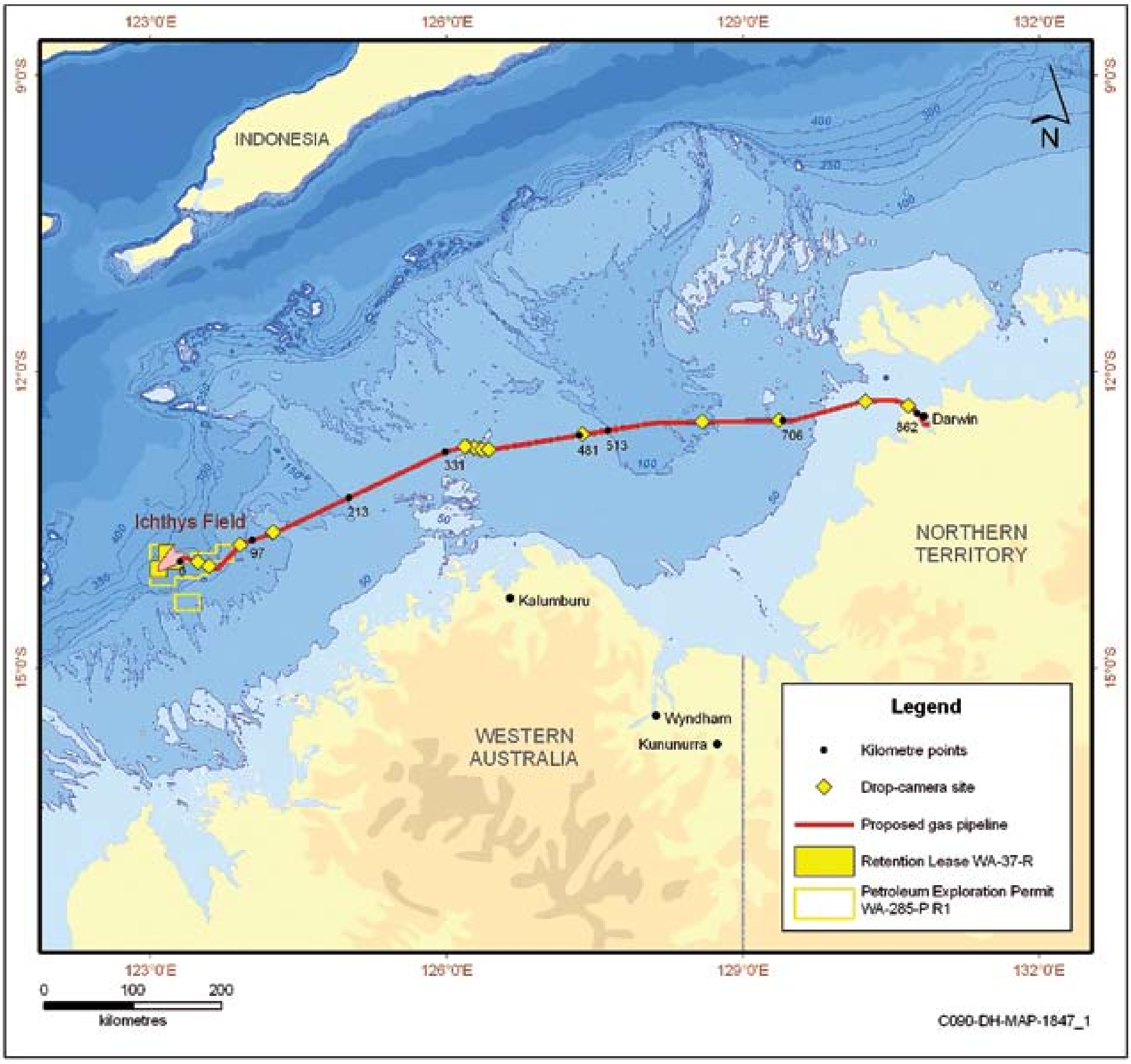


Figure 3-8: Survey sites for epibenthic communities along the proposed pipeline route

The benthic communities recorded along the pipeline route can be described in relation to the seven sections of seabed types identified through the geophysical survey from the Ichthys Field (KP 0) to Darwin Harbour (KP 860) as described in Section 3.2.3. Benthic biota recorded in the drop-camera investigations were as follows:

- **KP 0 to KP 97:** A single calcarenite outcrop 3 m high, approximately 600 m long and 200 m wide at KP 36 was the only notable hard substrate area recorded in this section during the geophysical surveys. This feature was not captured during the drop-camera survey. Occasional sea pens (family Pteroeididae) and sea whips were recorded on the clay–silt substrate at KP 36 and KP 81.
- **KP 97 to KP 213:** An isolated area of megaripples (with a crest height of 0.15 m and a wavelength of around 9 m) is present between KP 112 and KP 120, with some small patches of low-relief subcrop. Drop-camera surveys at KP 120 recorded sea fans and sea whips (*Junceella* spp.), feather stars, bryozoans, soft corals (*Dendronephthya* spp.), starfish or sea stars (class Asteroidea) and sponges.
- **KP 213 to KP 331:** No substantial areas of outcrops or hard substrate are present, so no drop-camera surveys were conducted in this section.
- **KP 331 to KP 481:** Eight drop-camera survey sites were included in this section (between KP 352 and KP 379) in order to investigate the various areas of hard substrate. Rocky outcrops supported epibenthic fauna at relatively high abundances, particularly feather stars. Sea pens, sea fans, sea whips, soft corals of the genus *Dendronephthya*, bryozoans, hydroids, and sponges were also recorded.

- **KP 481 to KP 513:** The subcrops in this area are flanked by clay–silt sand and interspersed with sandy gravel patches. A drop-camera survey at KP 484 recorded sea fans, sea whips, feather stars, soft corals of the genus *Dendronephthya* and sponges at low densities.
- **KP 513 to KP 706:** A small number of feather stars and a grinner fish (family Synodontidae) were recorded at KP 617. The drop-camera survey at KP 701 did not record any epibenthic animals, though the fine-sand substrate was peppered with small holes (<50 mm in diameter) indicative of burrowing invertebrates such as bivalves, shrimps and polychaete worms.
- **KP 706 to KP 862:** Drop-camera surveys at KP 848 recorded a sparse epibenthic fauna, predominantly made up of colonial hydroids with some sea pens, feather stars and ascidians (sea squirts of the class Ascidiacea). Similar species were recorded at KP 799, along with sparse sea whips, bryozoans and starfish (URS 2009a).

Pockmarks with diameters between 5 and 10 m were recorded along approximately a quarter (23%) of the total length of the pipeline route during the geophysical survey (Neptune Geomatics 2009). Pockmark density varied, with more than 10 pockmarks per hectare being considered to be "high" density. These features were also recorded in benthic surveys along the route of the Bayu–Undan Gas Pipeline in the Timor Sea (LeProvost, Dames & Moore 1997).

Pockmarks may be a focal point for benthic fauna in some instances, although the mechanisms and time-scale of their formation are not well defined (Brothers et al. 2009). Because pockmarks are widely distributed, any disturbance to them as a result of pipe-laying for the Ichthys Project is not considered to pose a threat to these benthic habitats on a regional scale.

In summary, benthic communities along the pipeline route are sparsely distributed and are mainly associated with hard substrates. Epibenthic species in the communities surveyed are common throughout north-west Australian offshore waters and are not considered to be of particular significance in the context of the Project.

3.2.8 Protected species

A number of threatened marine species that may be present in the offshore development area are protected under Commonwealth legislation, Northern Territory legislation or international agreements.

Commonwealth and Northern Territory legislation

The *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) provides a legal framework to protect and manage nationally and internationally threatened plants and animals—defined as "matters of national environmental significance". Threatened species may be listed under the EPBC Act in one of several categories depending on their population status (e.g. "critically endangered", "endangered", "vulnerable", and "conservation dependent"). In addition, a range of marine and migratory species are protected under the EPBC Act as they are listed in international treaties and conventions for the protection of wildlife (described below).

All cetaceans and many other large marine animals are protected under the EPBC Act. The Act also established the Australian Whale Sanctuary, which encompasses the portion of Australia's exclusive economic zone (EEZ) outside state waters—generally to 200 nautical miles from the coast, but further in some areas to include offshore territorial waters around islands such as Christmas, Cocos (Keeling), Norfolk, Heard and McDonald islands. The Ichthys Field lies inside the Australian Whale Sanctuary. It is an offence to kill, injure, take, trade, keep, move or interfere with a cetacean in the sanctuary.

The assessment of the conservation status of each wildlife species in Northern Territory waters is undertaken by the Biodiversity Conservation Unit of the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) under Section 29 of the *Territory Parks and Wildlife Conservation Act* (TPWC Act). The Northern Territory's Threatened Species List classifies threatened species under a number of categories, including "critically endangered", "endangered", "vulnerable", "near threatened", "data deficient" and "not threatened in the Northern Territory".

Table 3-1 lists threatened marine species that may be present in or near the offshore development area and that are listed as "critically endangered", "endangered" or "vulnerable" under the EPBC Act, TPWC Act or international conventions. It should be noted that other marine species that fall under less critical conservation categories (such as listed "cetacean" or "migratory" species, or "near threatened" species) also occur in the offshore development area; key species from these categories are discussed further in this section.

International protection and conservation status

Species of marine animals that are considered to be globally under threat of extinction may be listed on *The IUCN Red List of Threatened Species* maintained by the International Union for Conservation of Nature and Natural Resources (IUCN). They may otherwise be protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora ("CITES") or by the Convention on the Conservation of Migratory Species of Wild Animals ("the Bonn Convention"). Species that are protected by such conventions and laws are listed in Table 3-1. In the case of the IUCN Red List, only those species that are listed as vulnerable, endangered or critically endangered have been included.

Table 3-1: Protected species that may be present in or near the offshore development area and along the proposed pipeline route

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention§	CITES#
Cetaceans: whales						
Balaenoptera musculus	Blue whale	E	–	E	I	I
Megaptera novaeangliae	Humpback whale	V	–	V	I	I
Reptiles						
Caretta caretta	Loggerhead turtle (pipeline route only)	E	E	E	I	I
Chelonia mydas	Green turtle	V	–	E	I	I
Dermochelys coriacea	Leatherback turtle	E	V	CR	I	I
Eretmochelys imbricata	Hawksbill turtle (pipeline route only)	V	–	CR	I	I
Lepidochelys olivacea	Pacific ridley turtle** (pipeline route only)	E	–	E	I	I
Natator depressus	Flatback turtle	V	–	–	II	I
Cartilaginous fish: sharks						
Pristis zijsron	Green sawfish (pipeline route only)	V	V	CR	–	I
Rhincodon typus	Whale shark	V	–	V	II	II
Ray-finned fishes						
Hippocampus kuda	Spotted seahorse	–	–	V	–	–
Hippocampus planifrons	Flat-faced seahorse	–	–	V	–	–
Hippocampus spinosissimus	Hedgehog seahorse	–	–	V	–	–

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
E = Endangered; V = Vulnerable.

‡ International—IUCN: The IUCN Red List of Threatened Species.
CR = Critically Endangered; E = Endangered; V = Vulnerable.

§ International—Bonn Convention: Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals.
I = Appendix I Endangered Migratory Species; II = Appendix II Migratory Species.

# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

** The Pacific ridley turtle is also known as the olive ridley turtle.

Cetaceans

Cetaceans that occur in the North West Shelf and Oceanic Shoals bioregions include baleen whales, toothed whales and dolphins. In order to characterise the baseline abundance and diversity of marine mammals in the offshore development area, vessel-based cetacean surveys were conducted by the Centre for Whale Research (CWR) between August and November 2006 and in July and August 2007. To provide a broader, inter-regional context, aerial and vessel-based cetacean surveys were also conducted in the Kimberley Bioregion, at Camden Sound, Pender Bay and the Maret Islands (Figure 3-9). All surveys were timed to coincide with the period of peak seasonal presence of humpback whales and with pygmy blue whale migrations. The results of these studies are described briefly below, while more detail is provided in Appendix 4.

In addition, an acoustic logger was deployed by Curtin University's Centre for Marine Science and Technology near the northern edge of the WA-285-P permit area from September 2006 to September 2008 to record vocalising cetaceans and other marine noise (see Section 3.2.4 *Underwater noise*).

Humpback whales

Humpback whales are the most common whale species observed in the North West Shelf Bioregion, and are seasonally abundant between August and October.

Australia has two discrete populations of humpback whales, one migrating along the west coast and the other migrating along the east coast. The humpback whale stock that winters off Western Australia is known as the Group IV (Breeding Stock D) population (Jenner, Jenner & McCabe 2001), and is thought to have a total population of between 30 000 and 38 000 whales (Branch 2006).

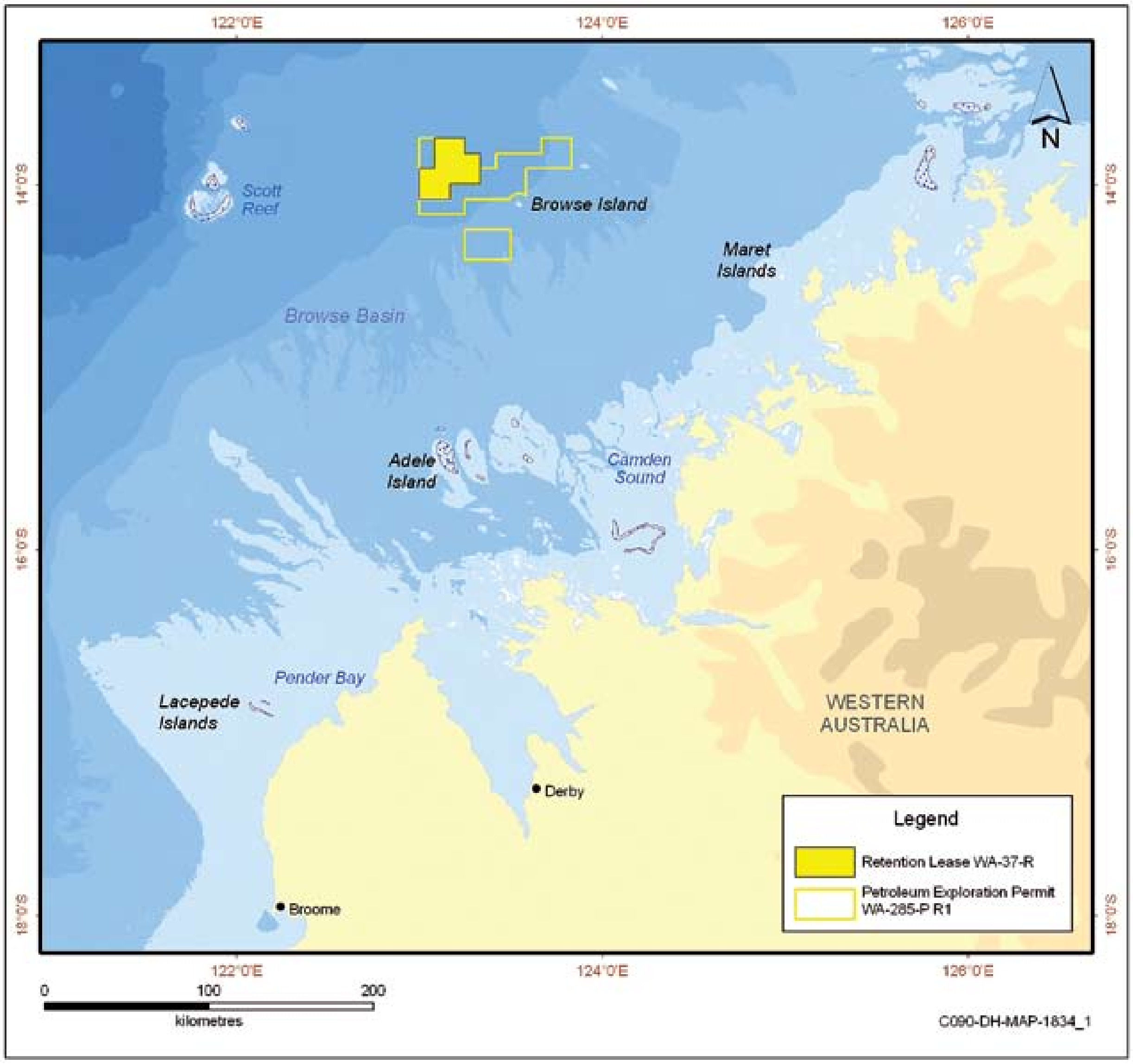


Figure 3-9: The Kimberley coast of Western Australia and the Ichthys Project's offshore development area

Stock D humpback whales migrate annually from their Antarctic feeding grounds to their breeding and calving areas off the Kimberley coast. The known calving area for Stock D humpback whales covers approximately 23 000 km^2 from the Lacepede Islands in the south to Adele Island in the north and to Camden Sound in the east (Jenner, Jenner & McCabe 2001). Calving occurs between June and November, with the peak of the southbound migration between late August and early September; cow-and-calf pairs trail the main migratory movement by three to four weeks (Chittleborough 1965).

Two humpback whales were recorded in vessel surveys south of Browse Island exhibiting swimming and diving behaviour that is consistent with feeding. These observations were considered unusual as humpback whales are thought to fast during their northern migration. This event coincided with a +0.5 °C temperature front and very high levels of bird, fish and other wildlife activity in the area. Pilot whales also appeared to be feeding in the same area (see Appendix 4).

Underwater noise logging suggested that humpback whales visited the offshore development area between July and September each year, with peak numbers recorded in mid-August (McCauley 2009).

There is no evidence from this study that the offshore development area is a calving ground for humpback whales, although the nearshore waters of the Kimberley Bioregion are known to be used for calving and resting. Humpback whale densities recorded in the field surveys were significantly higher in Camden Sound and Pender Bay than in the Browse Basin (Table 3-2). Whales observed in Pender Bay exhibited passive behaviour at the surface suggesting that the area is used for resting. Cow–calf pods appear to congregate in the area between Pender Bay and the Lacepede Islands during mid-September, using the area as a staging point and resting place prior to beginning their southern migration (see Appendix 4).

Table 3-2: Total humpback whales recorded during six vessel surveys in 2006 and 2007

	Browse Basin	Camden Sound	Pender Bay
Whales	21	486	263
Pods	13	325	182
Pods with calves	1	25	18

Source: see Appendix 4.

Blue whales

Two subspecies of blue whale are found in the southern hemisphere: the "true" blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*Balaenoptera musculus brevicauda*). Pygmy blue whales have been observed on many occasions during the winter months in locations such as the Savu Sea west of Timor (B. Kahn, Apex Environmental, pers. comm. 22 February 2006) and have been recorded along the far northern Kimberley coast of Western Australia at Cape Londonderry (Dr Deborah Thiele, Deakin University, pers. comm. 15 April 2007). While pygmy blue whales have been recorded in the Kimberley region, true blue whales are uncommon north of 60°S (Branch et al. 2007).

Like other rorquals (baleen whales of the family Balaenopteridae), pygmy blue whales are assumed to breed in the tropical north. Previous studies on the distribution of pygmy blue whales and blue whales in the southern hemisphere suggest that the Western Australian continental slope is a likely migratory path between a southern feeding area and a northern calving area; the location of this northern breeding ground is currently unknown (Branch et al. 2007). There is no consensus on the size of the pygmy blue whale population (DEH 2005a), but in 1996 the Australian Nature Conservation Agency estimated there to be 6000 animals in the southern hemisphere (Bannister, Kemper & Warneke 1996).

No blue whales or pygmy blue whales were observed in vessel surveys of the offshore development area (see Appendix 4). Noise from a pod of around six pygmy blue whales was recorded within a 75-km radius of the offshore development area on one occasion (in October 2006) during the two-year noise-logging study. Based on this and other noise-logging studies in the north-west of Australia, pygmy blue whales are believed to utilise an offshore migration path in water depths of around 500 m (McCauley 2009). These depths occur around 90 km north-west of the Ichthys Field.

Minke whales

Antarctic minke whales appear to migrate from southern feeding grounds in the summer to northern tropical feeding grounds in winter months. However, the detailed pattern of migration is still unclear and may be quite complex. In the north-east Pacific, for instance, it has been suggested that some minke whales are migratory while others form a resident population. In Australia, it is known that dwarf minke whales occur broadly from Victoria to northern Queensland between March and October, with the maximum number of sightings on the northern Great Barrier Reef in June and July.

A small number of minke whales (seven) were recorded in the offshore development area during vessel surveys. One was positively identified as the dwarf subspecies (see Appendix 4). Noise from minke whales of both the dwarf and Antarctic subspecies was recorded at the offshore development area in August and September 2006 (McCauley 2009).

Toothed whales and dolphins

Information on toothed whale and dolphin species off the Kimberley coast is limited, especially in offshore waters. In total, 21 species of toothed whale and dolphin could occur in the offshore development area (DEWHA 2009a). Species recorded by Jenner, Jenner and McCabe (2001) in the Kimberley region included false killer whales, dwarf spinner dolphins, spinner dolphins, bottlenose dolphins and Australian snubfin dolphins. Sperm whales have also been recorded in the Kimberley (Townsend 1935). Fifteen species of dolphins and toothed whales were observed in vessel surveys in the offshore development area. In particular, large numbers of Indo-Pacific bottlenose dolphins, long-beaked common dolphins, spinner dolphins, dwarf spinner dolphins, pantropical spotted dolphins and offshore bottlenose dolphins were recorded, along with smaller numbers of false killer whales, melon-headed whales and short-finned pilot whales (see Appendix 4).

The Australian distribution of short-finned pilot whales is not well known. This species prefers deep water and is found at the edge of the continental shelf and over deep submarine canyons (Bannister, Kemper & Warneke 1996). The short-finned pilot whale is not particularly migratory but inshore–offshore movements are determined by squid spawning patterns and the species is found inshore primarily during the squid season (see Appendix 4).

The false killer whale is also an oceanic species and has been reported to be widely distributed in deep tropical, subtropical and temperate waters globally. Although tending to prefer warmer waters, it is reported to live in water temperatures ranging from as low as 9 °C to up to 31 °C (Stacey, Leatherwood & Baird 1994).

The number of cetacean species observed in the surveys of the offshore development area is relatively high compared with previous studies in other regions of Western Australia. The very large pods of oceanic dolphins, for example, suggest that there is a substantial underlying food web in the area (see Appendix 4).

Dugongs

The dugong (*Dugong dugon*) has a range that extends from East Africa around the Indian Ocean to the western Pacific. In Australia, the species occurs along the northern coastline from Shark Bay in Western Australia to Moreton Bay near Brisbane, Queensland (NRETAS 2009a).

Dugongs are herbivorous and demonstrate a strong dietary preference for seagrasses, although they will also eat algae (Anderson 1982; Marsh 1999; Marsh et al. 2002). Dugongs are usually found in coastal areas such as shallow protected bays and mangrove channels and in the lee of large inshore islands where seagrass grows (Heinsohn, Marsh & Anderson 1979). However, they have also been recorded further offshore in areas where the continental shelf is wide, shallow (up to 37 m deep), and protected (Lee Long, Mellors & Coles 1993; Marsh et al. 2002).

Given that water depths in the Project's offshore development area range from 190 to 250 m, the presence of feeding habitat for dugongs is limited. During vessel surveys only one dugong was observed in the vicinity of the Ichthys Field. Dugongs were recorded more commonly in aerial and vessel-based surveys throughout the coastal survey areas (see Appendix 4).

In Northern Territory waters, aerial surveys in the Anson–Beagle Bioregion have recorded large numbers of dugongs around the Vernon Islands and Gunn Point, 30–50 km north-east of Darwin Harbour. Satellite-tracking data showed that dugongs can move long distances (e.g. 300 km) and dugongs tagged around the Vernon Islands spent time in Darwin Harbour, around the Tiwi Islands and as far west as Cape Scott and Cape Ford south of the Peron Islands, 100–120 km south-west of Darwin (Whiting 2003). Seagrass habitat is rare in this bioregion and dugongs have instead been observed foraging on intertidal rocky reef flats that support sponges and algae (Whiting 2008).

Dugongs also occur in waters off the Gulf of Carpentaria and Arnhem Land (NRETAS 2009a). Areas identified by the Parks and Wildlife Service of the Northern Territory (PWSNT) as key sites for the conservation of dugong and seagrass habitat include the north coast of the Tiwi Islands and Cobourg Peninsula, and Blue Mud Bay, Limmen Bight and the Sir Edward Pellew Islands on the east coast of Arnhem Land (PWSNT 2003).

Recent genetic research indicates that there is a significant level of gene flow in the dugong populations around the tropical Australian coast. Management units are consequently difficult to define. There also appears to be gene flow between the dugong populations in Australia and those in neighbouring countries (McDonald 2005).

Turtles

Six species of marine turtle are known to occur in the waters of northern Western Australian and the Northern Territory—the green turtle, flatback turtle, hawksbill turtle, loggerhead turtle, leatherback turtle and the Pacific ridley turtle. Of these, the green, leatherback and flatback turtles could occur in the vicinity of the Ichthys Field, while all six species could occur along the subsea pipeline route (Table 3-1) (DEWHA 2009a).

The green turtle is the most common turtle species found in Western Australia, and occurs from as far south as Rottnest Island, north through Shark Bay and the Houtman Abrolhos islands to coastal beaches in the Gascoyne and Pilbara regions, Barrow Island and some islands of the Montebello Islands and the Dampier Archipelago. In the Kimberley Bioregion (and offshore to the North West Shelf and Oceanic Shoals bioregions) green turtles nest on the Lacepede Islands, with smaller, regionally important nesting stocks visiting Browse Island and the Scott and Ashmore reefs (DEC 2009). Browse Island and Scott Reef have been gazetted as nature reserves primarily because of their importance as green turtle habitat.

Turtle populations on the Kimberley coast and offshore islands, including the Maret Islands, Montalivet Islands, Lacepede Islands and Browse Island, were studied by RPS Environmental in the 2006–07 nesting season. Green turtles were by far the most common species recorded, with the largest rookeries identified on the Lacepede Islands and Maret Islands (see Figure 3-9). Green turtles were also observed nesting at Browse Island, but in fewer numbers than on islands closer to the mainland (see Appendix 4).

A brief tag-and-release program conducted at Browse Island in November 1991 recorded 59 green turtles nesting on the beaches on one night and 40 turtles on the following night; 11 of these were the same individuals. While this period was in advance of the expected peak of seasonal nesting activity, these green turtle densities were considered a reasonable guide to usage of Browse Island, and indicative of a nesting attendance of hundreds of female green turtles for that summer (Bob Prince, Senior Research Scientist, Department of Environment and Conservation, Western Australia, pers. comm. November 2009).

Green turtles are not known to nest in the Anson–Beagle Bioregion in the western Northern Territory, the species rather utilising nesting areas in north-eastern Arnhem Land. The northern Western Australian and eastern Northern Territory groups of green turtles appear to represent two distinct "management units" that are separated geographically (see Appendix 4). However, subadult green turtles are known to use an important feeding area within the island reefs at the northern end of Fog Bay approximately 80 km south-west of Darwin Harbour (Chatto & Baker 2008).

Flatback turtles migrate over long distances along the northern Western Australian coastline from rookeries in the Pilbara region into the Kimberley region, and as far as the Northern Territory. They generally forage in turbid, shallow inshore waters in depths of 5–20 m. Flatback turtle nests were recorded on beaches in the Maret, Montalivet and Lamarck islands in the field surveys and the population of female turtles nesting at these islands was estimated at 218–251 individuals. The species was not recorded in surveys of Browse Island or the Ichthys Field (see Appendix 4).

Flatback turtles are abundant throughout the Anson–Beagle Bioregion, with significant nesting areas located at North Peron Island, Five Mile Beach, Bare Sand Island, Quail Island and Indian Island (see Figure 3-10). Beaches around the Cox Peninsula are also utilised, although to a lesser extent, with informal observations suggesting a nesting density of about 20 nests per year (Dr M. Guinea, marine biologist, Charles Darwin University, pers. comm. September 2008). Similarly, flatback turtles nest in low densities on Casuarina Beach, which is located close to residential areas of Darwin's northern suburbs. While important from the perspective of public education, Casuarina Beach is not considered a significant breeding area for marine turtles on a bioregional scale (Chatto & Baker 2008).

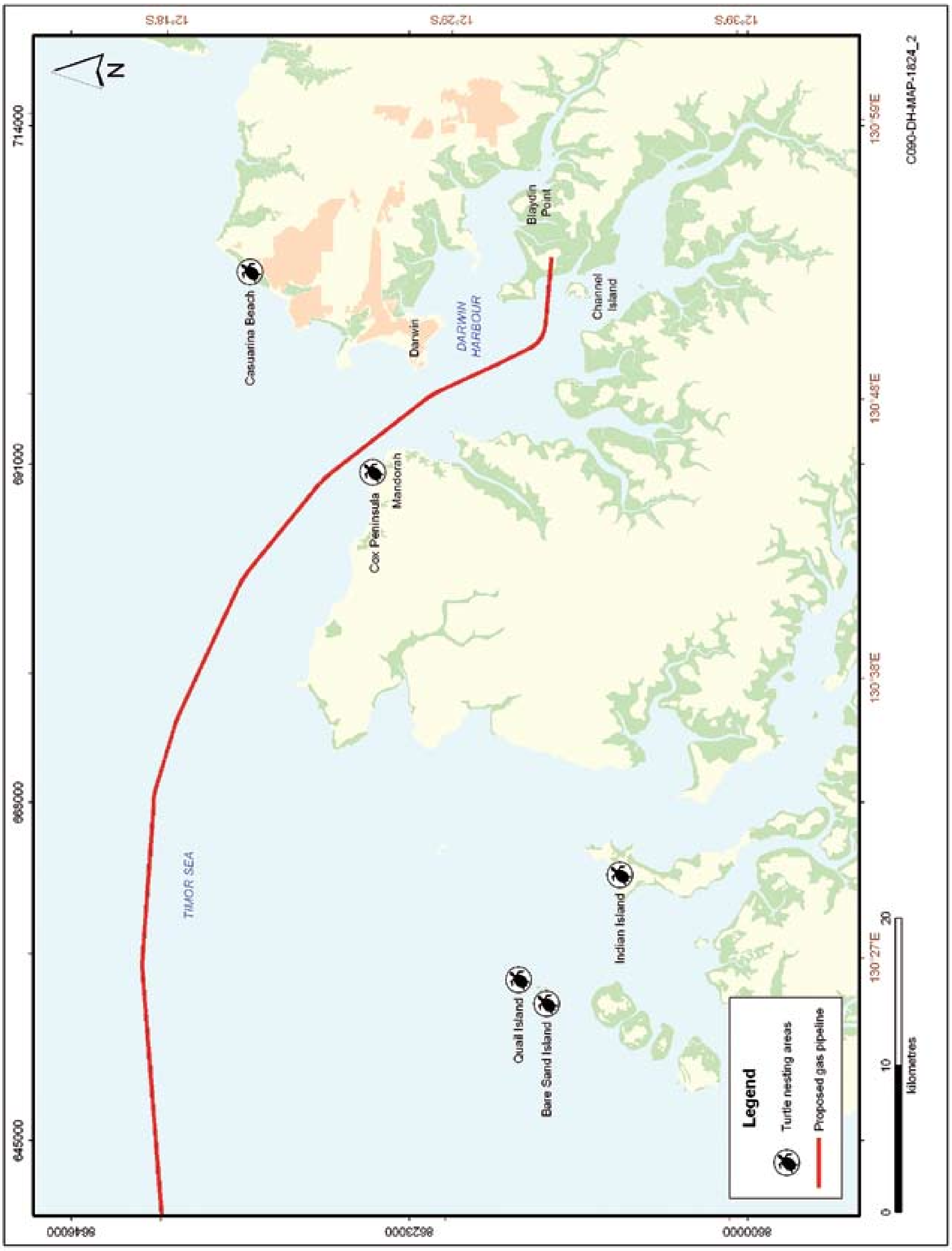


Figure 3-10: Turtle nesting beaches of the Anson–Beagle Bioregion

Leatherback turtles are presumed to migrate to Australian waters from nesting populations in Indonesia, Papua New Guinea and the Solomon Islands. Little is known of the biology of leatherback turtles in Australia: no major rookeries are known and mating has not been recorded, although sightings of the species have been made near Cape Leveque in the Kimberley Bioregion. Leatherback turtles were recorded off Browse Island during vessel-based whale surveys, and the species was occasionally observed in the survey of the Maret Islands and surrounds. No leatherback turtle nesting areas were identified in field surveys (see Appendix 4). Leatherback nesting activity is not known to occur in the Anson–Beagle Bioregion (Chatto & Baker 2008).

The mating and foraging behaviour of hawksbill turtles in Western Australia is not well known, and hawksbill tracks were recorded rarely in the field surveys of the Maret Islands and surrounds. Hawksbill turtles were not observed in offshore waters of the Browse Basin during field surveys. Nesting activity for this species is not known to occur in the Anson–Beagle Bioregion, but there is a significant hawksbill feeding area within the island reefs at the northern end of Fog Bay (Chatto & Baker 2008).

Pacific ridley turtles are not known to nest in Western Australia and were not recorded in field surveys in the Maret Islands and surrounds. The species does nest occasionally in the Anson–Beagle Bioregion, at Indian Island and Bare Sand Island (Figure 3-10), but in low numbers. More significant nesting areas for Pacific ridley turtles are located on the Tiwi Islands and in eastern Arnhem Land (Chatto & Baker 2008).

No mating or nesting of loggerhead turtles is known in the Kimberley Bioregion or the Anson–Beagle Bioregion. Loggerhead turtles were spotted during aerial surveys in the Maret Islands and the surrounding areas, but not during surveys of the Browse Basin (see Appendix 4).

Ray-finned fishes

Three seahorse species (family Syngnathidae) that appear on the IUCN's Red List (see Table 3-1) could potentially occur in the offshore development area; however, the distribution ranges of these are not well known. The flat-face seahorse has only been recorded previously in Shark Bay and Broome, and the presence of the hedgehog seahorse in Australian waters has not been confirmed (Seahorse Australia 2008). The spotted seahorse inhabits sheltered bays and estuaries from Onslow in Western Australia's Pilbara region, northwards across the Indo-Pacific region (Allen & Swainston 1988).

None of these seahorse species were recorded in surveys of an intertidal pool at Browse Island (see Appendix 4).

Seabirds

Seabirds in the offshore area around the Ichthys Field and Browse Island, and to the west as far as Scott Reef, were recorded during vessel surveys conducted by the CWR in June and July and in October and November 2008. Seabirds observed included frigatebirds, boobies, terns, noddies, tropicbirds, petrels, shearwaters and gulls, with the brown booby the most common species recorded. Of the species recorded, a number are migratory species listed under the EPBC Act, including the streaked shearwater, brown booby, masked booby, lesser frigatebird, Wilson's storm-petrel, bridled tern, lesser crested tern and little tern (see Appendix 4). These migratory species can be expected to pass through the offshore development area in low numbers.

Within the region, the Roebuck Bay – Eighty Mile Beach area on the Kimberley coast (approximately 450 km south-south-west of the Ichthys Field) is identified as an internationally important site for migratory birds that utilise the East Asian – Australasian Flyway. Hundreds of thousands of shorebirds have been recorded there, arriving during the southern migration period between August and November and with many birds staying through the non-breeding period from December to February (Bamford et al. 2008). Flight paths between key foraging and resting areas in the region are not well known and may vary between species. Ashmore Reef (around 160 km north of the Ichthys Field) is also recognised as regionally important for seabirds, with 16 species known to breed there; there are, for example, large nesting colonies of sooty terns, common noddies, bridled terns and crested terns (Milton 2005).

3.2.9 Other marine megafauna

Vessel surveys by RPS Environmental and the CWR and acoustic loggers utilised for cetacean surveys also provided data on fish, sharks, rays and seasnakes in the Ichthys Field area. Seasnakes were observed in the offshore development area but were not close enough to identify to species level. Observations included a leopard shark, a mako shark, two hammerhead sharks and one whale shark, as well as 22 manta rays. Large numbers of flying fish and jellyfish were also recorded (see Appendix 4).

Fish surveys in an intertidal pool at Browse Island identified 32 species, including *Abudefduf vaigiensis* (family Pomacentridae), *Ecsenius oculus* and *Cirripectes filamentosus* (family Blenniidae) and a *Gymnothorax* sp. (family Muraenidae). All of the species identified are common in the Indo-Pacific region (see Appendix 4).

3.3 Nearshore marine environment

As described in Section 3.1.1, the nearshore development area includes the marine area from the entrance of Darwin Harbour to the coastal waters around Blaydin Point and Middle Arm Peninsula below the low-water mark (see Figure 3-2).

3.3.1 Darwin Harbour bathymetry

Darwin Harbour is a large ria system about 500 km^2 in extent. In its southern and south-eastern portions the Harbour has three main components—East Arm, West Arm and Middle Arm—that merge into a single unit, along with the smaller Woods Inlet, before joining the open sea. Freshwater inflow to the Harbour occurs from January to April, when estuarine conditions prevail in all areas (Hanley 1988).

Over the 6000–8000 years since the Harbour was formed by rising sea levels, erosion from the adjoining terrestrial environment has carried substantial quantities of sediment into its waters. This sediment now forms much of the intertidal flats that veneer the bedrock.

The proposed onshore development area is situated on land at the eastern end of Middle Arm Peninsula in the Harbour, between East Arm and Middle Arm. Both arms are the estuaries of rivers that drain the hinterland behind Darwin and Palmerston during the wet season. Elizabeth River flows into East Arm, while the Darwin and Blackmore rivers flow into Middle Arm.

The main channel of the Port of Darwin is around 15–25 m deep, with a maximum depth of 36 m (Figure 3-11). The channel favours the eastern side of the Harbour, with broader shallower areas occurring on the western side. Intertidal flats and shoals are generally more extensive on the western side of the Harbour than on the eastern side.

The channel continues into East Arm, towards Blaydin Point, at water depths of more than 10 m below LAT; the bathymetry in this area has been modified by dredging for the development of East Arm Wharf.

A slightly deeper channel extends into Middle Arm, up to the western side of Channel Island. A shallower channel (generally 10–15 m below LAT) separates Wickham Point from Channel Island.

3.3.2 Oceanography and hydrodynamics

Darwin Harbour is characterised by a macrotidal regime. Tides are predominantly semidiurnal (two highs and two lows per day), with a slight inequality between the successive tides during a single day. For a two-day period during neap tides there are nearly diurnal tide conditions (one high and one low per day). The lowest spring tides of the year occur during October, November and December. Mean sea level is approximately 4.0 m above LAT. Spring tides can produce tidal ranges of up to 7.5 m (0.0 m LAT at low tide to 7.5 m above LAT at high tide), while the neap-tide range can be as low as 1.4 m (3.1 m above LAT at low tide to 4.5 m above LAT at high tide) (Australian Hydrographic Service 2008).

Tidal excursions range from 8 to 15 km during spring tides and 2 to 8 km during neap tides (Hanley & Caswell 1995; Semeniuk 1985). The large tidal ranges produce strong currents that peak at speeds of up to 2–2.5 m/s. Tidal flows are also large: peak spring-tide flows have been measured along a line from East Point to Mandorah and are in the order of 120 000 m^3/s. Over a spring tide up to 1000 GL/s can pass through this area (Williams & Wolanski 2003). The major currents in the Harbour are illustrated for ebb tide and flood tide in figures 3-12 and 3-13 respectively.

The Harbour is considered to be well protected, with the majority of waves generated within the Harbour or in Beagle Gulf (Byrne 1988). The ambient wave climate during the summer months could reach heights of up to 1 m, although average wave height would be less than 0.5 m with periods of 2–5 s (Byrne 1988; GHDM 1997). Average wave conditions during the winter months are predicted to be even lower. It is considered that tsunamis and swell waves (long-period waves) are unlikely to occur in Darwin Harbour as a consequence of its orientation and the protection from ocean swells afforded by the Tiwi Islands (GHDM 1997).

Extreme wave conditions were modelled by GHDM using wind data from Cyclone Tracy in 1974. Waves with a "significant wave height" of 4.5 m and average periods of around 7.5 s were found to occur at the entrance to the Harbour. However, these waves were found to be affected by bathymetry and reduced to a height of around 0.7 m in shallower waters in the inner parts of the Harbour (GHDM 1997).

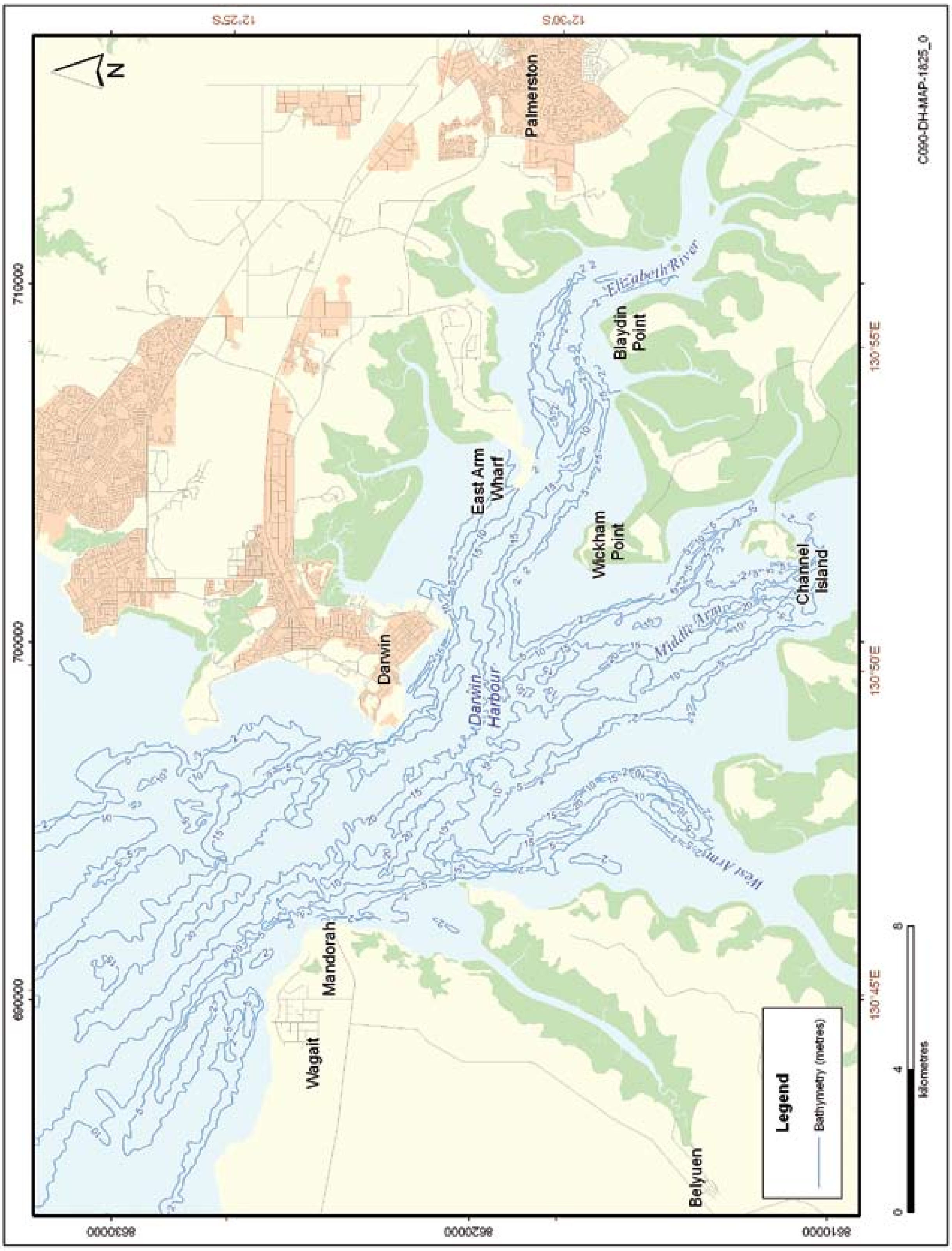
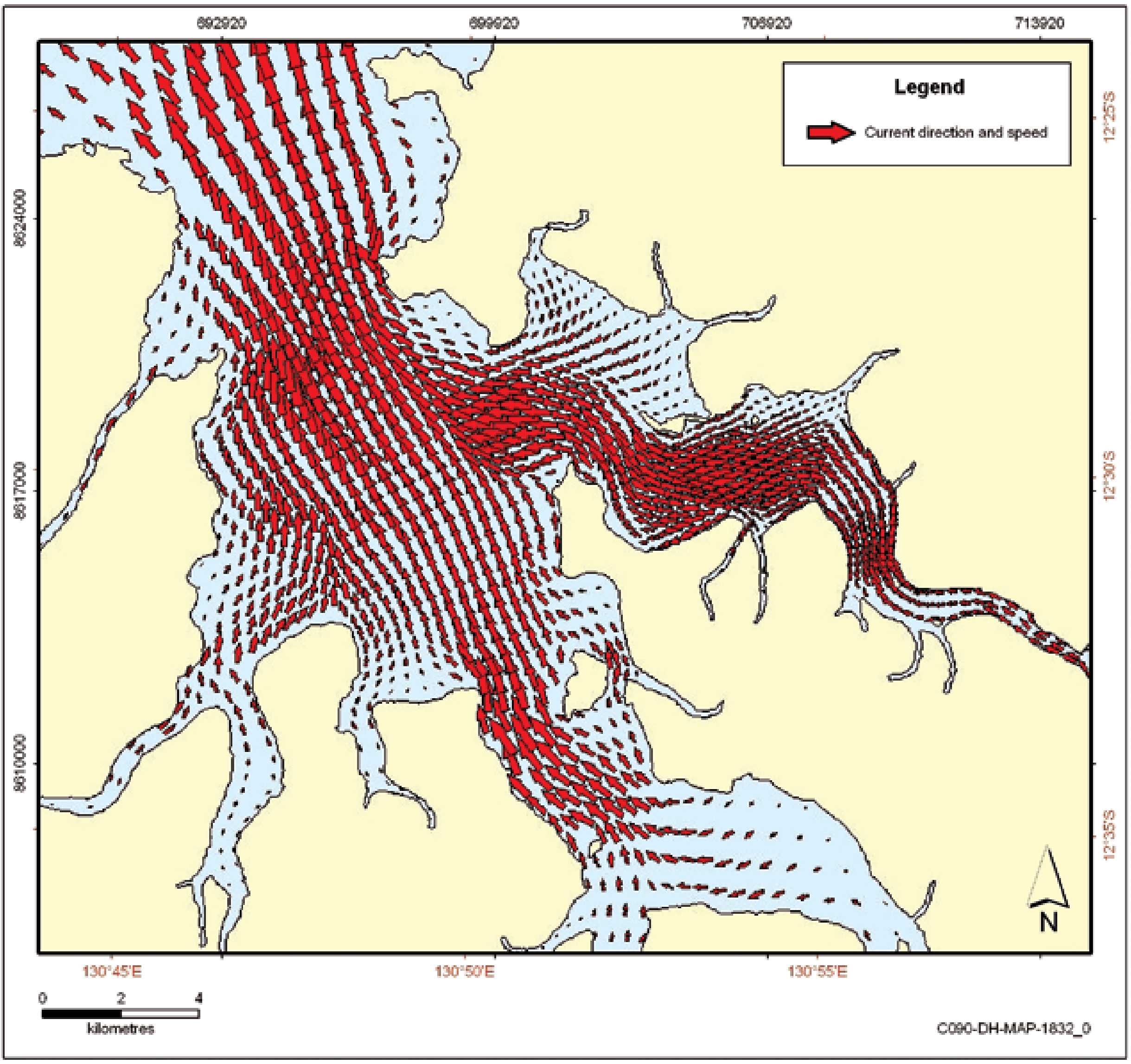


Figure 3-11: Bathymetry of Darwin Harbour



Source: APASA 2010.

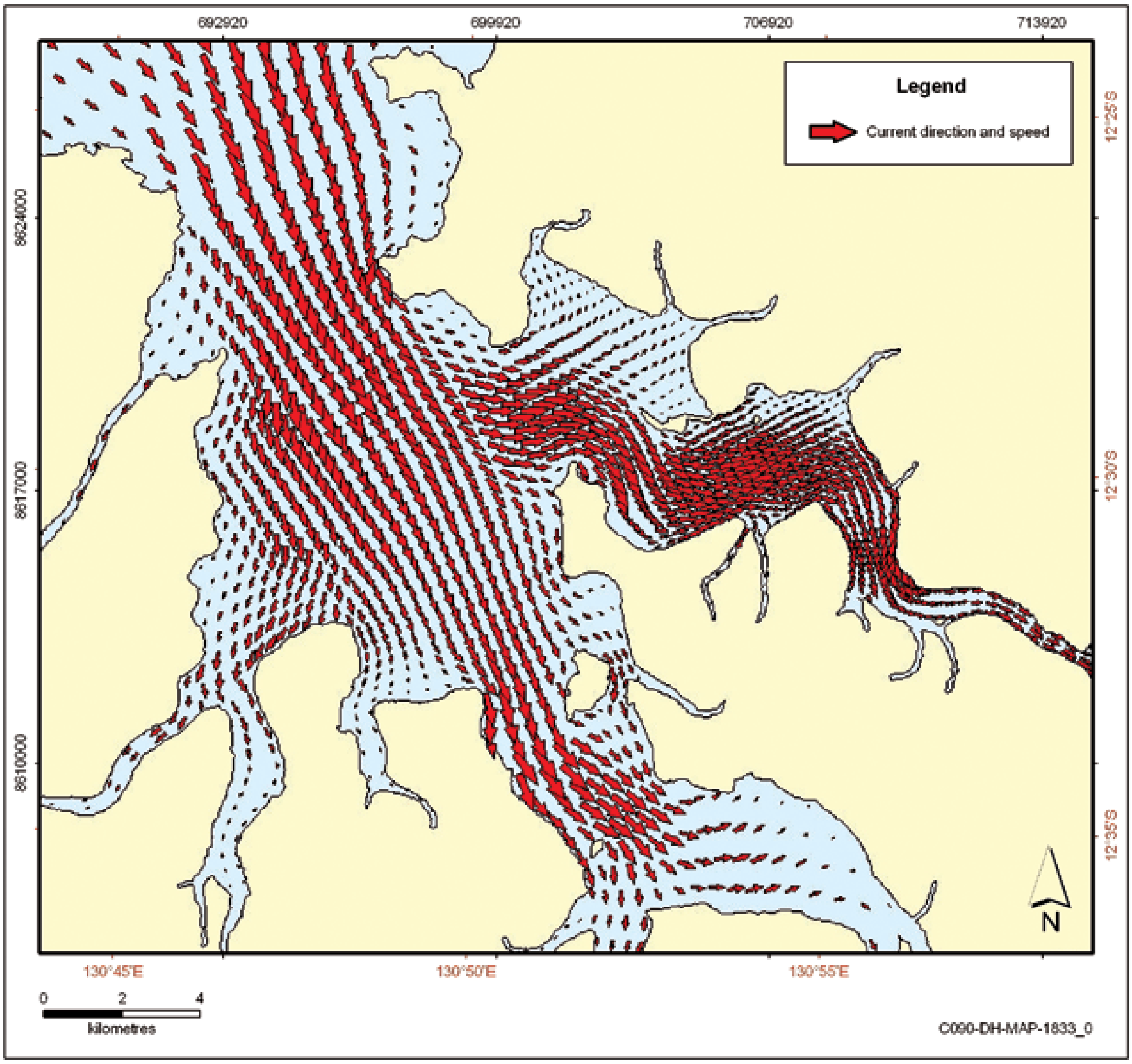
Figure 3-12: Major currents during ebb tide in Darwin Harbour

Storm tide predictions—which take into account cyclone storm surges together with the effects of frequent breaking waves ("wave set-up") and the influence of astronomical tide—indicate that temporary increases in sea level would occur during cyclone conditions at sites around Middle Arm Peninsula and East Arm (Table 3-3). The largest storm tide expected over a 100-year period (a 1-in-100-year event) is 4.9–5.1 m above mean sea level. As mean sea level is estimated at 4 m above LAT, this storm tide would therefore bring nearshore waters to a height of 8.9–9.1 m above LAT. Predictions over longer return periods, for 1-in-1000- and 1-in-10 000-year events, indicate even higher storm tides (Hennessy et al. 2004).

Table 3-3: Predicted storm tide heights for locations in the nearshore development area

Location	Storm tide height (m) relative to mean sea level (4 m above LAT)		
	1 in 100 years	1 in 1000 years	1 in 10 000 years
West Arm	5.1	6.4	7.6
Channel Island	5.1	6.4	7.7
Wickham Point	5.1	6.4	7.7
East Arm Wharf	4.9	6.0	7.0

Source: Hennessy et al. 2004.



Source: APASA 2010.

Figure 3-13: Major currents during flood tide in Darwin Harbour

3.3.3 Underwater noise

Underwater noise in Darwin Harbour is influenced by existing shipping traffic as well as by biological sources and weather (e.g. heavy rain). In order to characterise the acoustic environment in the nearshore development area, SVT Engineering Consultants conducted underwater noise monitoring in 2009 using hydrophones (SVT 2009a).

The readings obtained during the monitoring program can be broadly broken into three general frequency spectra:

- 0–50 Hz
- 50–2000 Hz
- >2000 Hz.

Within the 0–50 Hz spectrum most of the noise recorded was below 20 Hz. This is below the hearing range of most of the marine animals that occur in Darwin Harbour. Baleen whales are able to hear at this low frequency, but visit the Harbour very rarely.

The mid-frequency spectrum between 50 and 2000 Hz shows very wide variations in the ambient noise levels recorded, which is a result of the acoustic complexities of the area. Factors such as shallow water, variable depth of water, high tidal range (and the turbulence created by tidal flows), and variable seabed types cause wide variations in the propagation of noise through the water column. It was noted that sound pressure levels in the Elizabeth River were distinctly lower than those in the broader parts of East Arm (around 100 dB re 1 μPa^2/Hz, compared with around 150–170 dB re 1 μPa^2/Hz), as the shallower water, more complex landform and soft-bottom substrate in the river all reduce noise propagation.

The high-frequency >2000 Hz spectrum of ambient noise in the Harbour is dominated by the sound of snapping shrimp. This has a typical peak frequency of 5–7 kHz.

Targeted recordings of three tugboats under way in the Harbour (the *Marrakai*, *Ginga* and *Larrakia*) were typical of small diesel-powered vessels. These tugs generated point-source noise from propellers in the range 30–100 Hz, from their diesel engines in the range 100–1000 Hz, and from broadband propeller cavitation noise mainly up to 15 kHz, but extending as high as 96 kHz (the maximum for the hydrophone) at very close range (SVT 2009a).

Measurements of tugboats working alongside an LNG tanker (the *Energy Progress*) from a distance of 230 m recorded broadband noise at around 10 kHz, which is expected to have extended to much higher frequencies at closer range. Received levels of noise from this distance reached about 205 dB re 1 µPa (SVT 2009a).

Other prominent sources of noise in the nearshore marine environment include thunderstorms, lightning strikes and heavy wet-season rains, which generate noise at significant intensities. However, it is noted that these natural noise sources occur only seasonally, while vessel traffic in Darwin Harbour is active throughout the year.

3.3.4 Water quality

The Water Quality Protection Plan for Darwin Harbour was initiated in 2006 as part of the National Water Quality Management Strategy, a long-term plan developed by the Commonwealth, state and territory governments in 1992 to ensure that there would be a sustainable and nationally consistent approach to water-quality management (NRETAS 2007b). The plan aims to maintain the current quality of water resources in Darwin Harbour, and a key component of this management strategy has been the development of water-quality guidelines and objectives (NRETAS 2009b). These are based on the "declared beneficial uses" under the *Water Act* (NT), which are defined for the Harbour as "the protection of aquatic ecosystems, recreational water quality and aesthetics" (NRETA 2007a).

The range of water-related studies in Darwin Harbour is diverse with respect to the objectives, time frames, water-quality variables measured, and locations. The majority of these studies are descriptive and of short-term duration (less than one year) where the objectives have been to obtain baseline information. Most of the other studies are associated with environmental monitoring in response to potential impacts such as dredging, sewage discharge and runoff (Padovan 2003).

The first comprehensive water-quality study of Darwin Harbour was undertaken during 1990–91 for the main body of the Harbour and the entrances to East Arm, West Arm and Middle Arm. More recent comprehensive water-quality monitoring of the Harbour, from 2001 to 2005, expanded the range of locations to include the upper reaches of East Arm and Middle Arm, tidal creeks and Shoal Bay (WMB 2005).

Water quality in the Harbour is generally high, although naturally turbid most of the time. Water-quality parameters vary greatly with the tide (spring versus neap), the location of sampling (inner versus outer Harbour), and with the season (wet season versus dry season). The Darwin wet season extends from November to March and its effects on Harbour water quality (from high levels of surface runoff from the land) can last until April or May depending on the amount of rainfall received. Dry-season climate conditions prevail from May to September.

Tides have a marked effect on water clarity in the Harbour, with waters of neap tides being the clearest while spring tides carry quantities of sediment from the fringing mangroves (DHAC 2007) and bring fine sediments from the Harbour floor into suspension. The areas with the highest natural sedimentation are in the upper reaches of East Arm and Middle Arm. Medium levels of sedimentation occur in the seaward end of West Arm and the lowest levels are in the more open water areas such as East Arm Wharf, Larrakeyah and the seaward boundary (DHAC 2006). It is estimated that 60% of the Harbour's sediments originate from offshore. The remainder is deposited by rivers and creeks, derived predominantly from erosion of channel walls. Direct contribution to the Harbour from sheet erosion is likely to be limited because of the very low hill-slope gradients adjacent to the Harbour (DHAC 2006).

There is no evidence of widespread water or sediment pollution in the Harbour, although there is some localised pollution (Padovan 2003). Anthropogenic influences on Harbour water quality include the port operations at East Arm Wharf, historical industrial activities at Darwin Waterfront and Sadgroves Creek, and wastewater outfalls (URS 2004). The Power and Water Corporation discharges untreated macerated sewage to the Harbour from a sewage plant at Larrakeyah near the Darwin central business district (CBD) at rates of around 80 000 to 130 000 kL per month. Nutrient loads associated with these monthly discharges range between 3.16 t and 6.98 t of total nitrogen and 0.72 t and 1.36 t of total phosphorus (Power and Water Corporation 2006a).

There are increased levels of nutrients in Buffalo Creek and metals in the sediments at Iron Ore Wharf (near Fort Hill Wharf); however the ecological significance of these localised impacts is unclear. In addition, there is no evidence of hydrocarbon or pesticide pollution in the Harbour (DHAC 2007).

A summary of the seasonal, spatial and tidal processes affecting water quality in Darwin Harbour is presented in Table 3-4.

Table 3-4: Summary of processes affecting water quality in Darwin Harbour

Parameter	Influencing factors	
	Open Harbour	Tidal creeks
Temperature	Season	Season
Salinity	Season, location	Season, tide
Dissolved oxygen	Tide (minor)	Tide
pH	(none)	Season, tide
Turbidity and light attenuation	Season (minor), tide	Tide
Nutrients	(none)	Location

Source: Padovan 2003.

In order to characterise the existing conditions in the nearshore development area a water-quality survey was undertaken by URS from April to August 2008, designed to capture the effects of both the wet and the dry seasons. The study included measurement of physico-chemical water-quality parameters in the water column as well as assessment of total suspended solids (TSS). Sampling sites included in the survey are shown in Figure 3-14, while a summary of the average levels recorded is provided in Table 3-5. The results of the study are discussed below, with the full technical report (URS 2009b) provided as Appendix 9 to this Draft EIS.

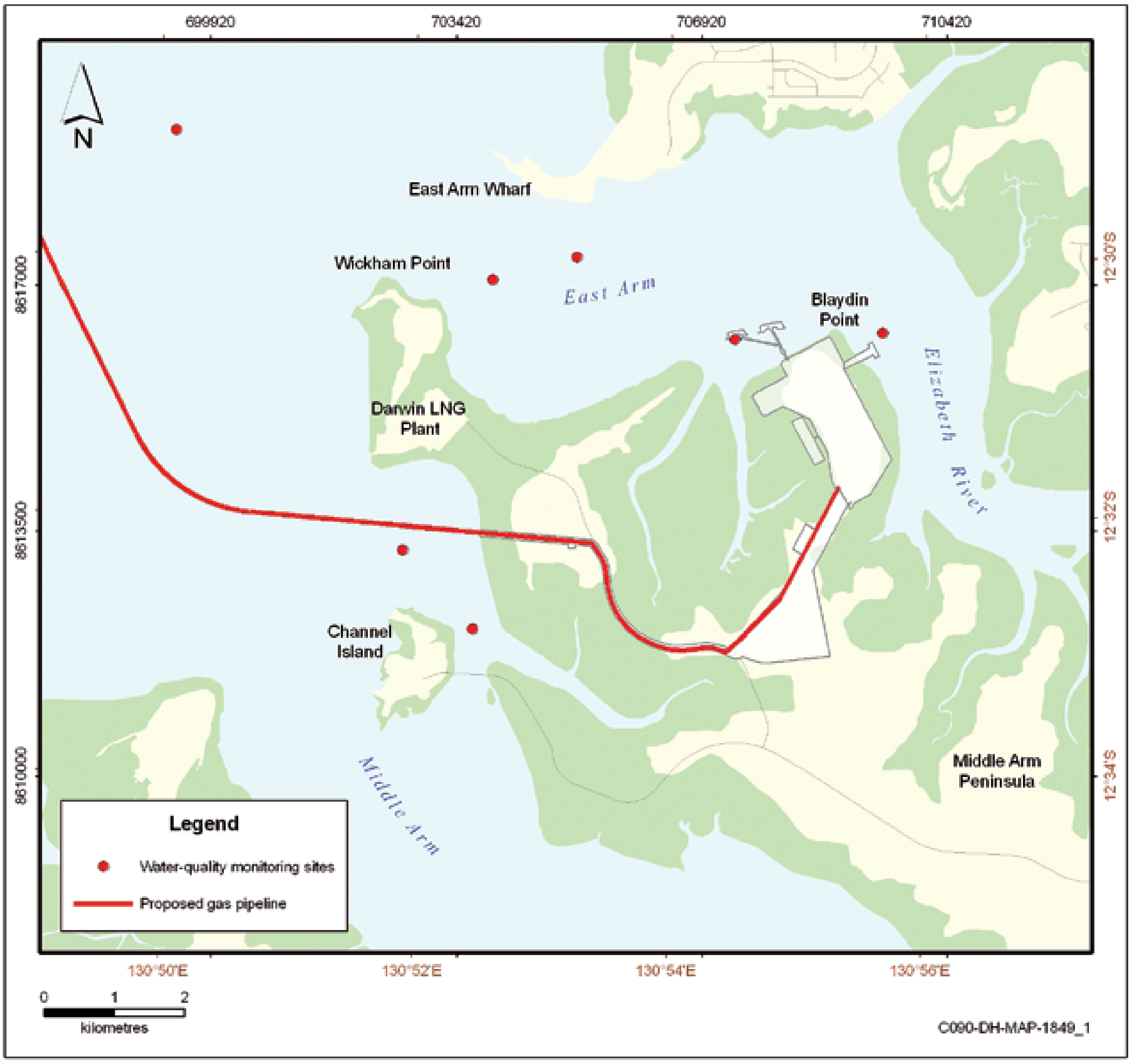


Figure 3-14: Nearshore water-quality sampling sites

Table 3-5: Mean water-quality levels recorded in the nearshore development area

Parameter	Dry season	Wet season
Temperature	24.5 °C	30.6 °C
Salinity	35.5 ppt*	29 ppt*
Dissolved oxygen	93.3%	87.8%
pH	8.4	8.1
Turbidity	3.0 NTU†	10.5 NTU†
Total suspended solids (TSS)	14.0 mg/L	14.1 mg/L

Source: URS 2009b.
* ppt = parts per thousand.
† NTU = nephelometric turbidity units.

Water temperature

Water temperatures in Darwin Harbour are typically high, and some seasonal variations do occur. Temperatures are lowest (23 °C) in June and July and highest (33 °C) in October and November (Padovan 1997).

Water temperatures measured in the nearshore development area by URS (2009b) ranged from 23.5 to 32.7 °C, with an average temperature of 30.6 °C in the wet season and 24.5 °C in the dry season. Comparison between sites over both the wet and dry seasons found that the water temperature was elevated by about 5 °C in the wet season. These distinct seasonal variations in sea-surface temperature have been shown in previous studies of the Harbour, for example by Michie, Grey and Griffin (1991). No significant difference in temperature was observed at any site as a result of either water column position (surface or bottom) or tidal flow (ebb or flood). Spatial uniformity in the Harbour has also been found to occur at sites located both in the upper reaches of Middle Arm and close to the Darwin CBD (Michie, Grey & Griffin 1991).

Salinity

Salinity in Darwin Harbour varies considerably during the year, particularly in East Arm, Middle Arm and West Arm where freshwater influence is greatest during the wet season. Sea water has a global average salinity of 35 parts per thousand (ppt) (DEH 2008). Salinities throughout the Harbour however are about 37 ppt during the dry season, with surface and bottom layers having similar levels. Salinity tends to be higher in harbours in the dry season owing to increased evaporation and less freshwater inflow. At the height of monsoonal inflow during February and March, areas in the middle of the Harbour such as Weed Reef can experience salinity levels as low as 27 ppt (Parry & Munksgaard 1995).

Salinities in the arms, which are strongly influenced by freshwater inflow, can drop as low as 17 ppt. The water at this time is highly stratified, with freshwater input from land-based catchments flooding the Harbour and overlying the intrusion of more dense and higher-salinity water from outside the Harbour, forming a classic "salt wedge" that is typical of estuarine systems. Parry and Munksgaard (1995) reported salinities on the bottom of the Harbour to be as much as 12 ppt higher than on the surface. As the rains cease, runoff decreases and salinities return to their higher dry-season levels (Parry & Munksgaard 1995).

Salinity levels recorded in the East Arm area by URS (2009b) ranged from 19.1 to 36.3 ppt. Mean salinity levels in the Harbour were lower in the wet season than in the dry season (Table 3-5). Under dry-season conditions, salinity was higher in upstream areas than downstream, but this trend was reversed in the wet season with freshwater input to the arms from rainfall. These variations in salinity according to location in the Harbour and according to season have also been previously reported by Michie, Grey and Griffin (1991) and Padovan (1997). No significant differences in salinity levels attributable to position in the water column were observed (URS 2009b)—this may have been a result of water sampling occurring in April and not earlier in the wet season when a significant salt wedge underlying a freshwater lens would likely have been present. Tidal flushing and a lack of major rainfall events during the wet-season sampling period may also have assisted with sufficient mixing of the water column at the sampling sites.

Dissolved oxygen

Harbour waters remain well oxygenated throughout the year, with levels typically ranging from 74% to 96% saturation, averaging around 84%. In a study by Padovan (1997) no seasonal effects were observed, and there were minor changes in oxygen levels with location in the main body of the Harbour. Dissolved-oxygen levels at sites closest to the Harbour's mouth were slightly higher than sites further into the estuary. In addition, oxygen levels during a spring-tide cycle were 7% higher at high tide than at low tide (Padovan 1997).

Dissolved-oxygen levels in tidal creeks fluctuate with the tidal cycle, with oxygen concentrations lowest during low tide. Oxygen levels in Blessers Creek (on the west side of, and adjacent to, East Arm Wharf) at low neap tide have been recorded at 60% saturation, compared with 90% at high tide (Parry & Munksgaard 1996). This indicates a certain oxygen demand in tidal creeks, probably from mangrove root systems and sediment infauna.

To date there are no reports of anoxia in undisturbed tidal creeks, and it is not known whether the conditions under which anoxia is most likely to occur have ever been sampled. These conditions are during small tidal movements in October and November when temperatures are highest and calm conditions prevail (Padovan 2003).

Dissolved-oxygen levels measured in the nearshore development area by URS (2009b) ranged from 74.4% to 103.0%[3], with an average saturation of 93%. Overall, dissolved oxygen was generally found to be higher in the dry season and in the main body of the Harbour, with decreasing levels further upstream. Higher dissolved-oxygen levels were recorded nearer the surface than at the bottom of the water column. No significant differences in dissolved-oxygen levels were observed between flood and ebb tides (URS 2009b).

pH

The pH of Darwin Harbour waters generally remains within a narrow range (8.3–8.6 with a mean of 8.5) throughout the main waterbody. Padovan (1997) found no seasonal or spatial effects on pH, and no tidal effects.

The pH of tidal creeks varies to a greater degree than the open Harbour waters and is affected predominantly by tide and season. During the dry season or periods of no freshwater inflow, the pH of Blessers Creek and Middle Arm was 0.3 pH units lower at low tide than at high tide (Parry & Munksgaard 1996). This indicates that processes occur in the mangrove environment that result in the slight acidification of inflowing waters.

Measurements recorded in the nearshore development area by URS (2009b) recorded a mean pH of 8.4 and a range from pH 7.8 to 8.5. In the upper reaches of Middle Arm and East Arm, mean pH levels were found to be lower (more acidic), with pH levels increasing (becoming more alkaline) in the main body of the Harbour in both wet- and dry-season sampling. No significant difference in pH attributable to water-column position or tidal state was observed (URS 2009b).

3 Percentage dissolved oxygen is derived using standard calculations between water temperature and dissolved-oxygen concentrations (e.g. in mg/L). Water-quality sampling probes perform this conversion automatically. However, this "standard" calculation is not accurate across all environmental conditions and, as a result, dissolved-oxygen levels greater than 100% can occur.

Turbidity and light attenuation

Light levels reaching the sea surface in the Harbour are very high. However, because of the high levels of suspended solids in the water column the light is rapidly dissipated and even within a depth of a few metres light levels can be greatly reduced. Turbidity is a measure of this "light-scattering" effect, and is measured in nephelometric turbidity units (NTU).

The most important factors affecting turbidity are the tidal cycle and location within the Harbour (Padovan 1997). Turbidity is highest during spring tides when current velocity, and therefore the capacity of the water to move sediment, is greatest (DHAC 2005). During the spring-tide cycle, turbidity is greatest at the midpoint between high and low water and least at slack water.

Turbidity is higher in the wet season than the dry season because of the influx of terrigenous sediments to Harbour waters through the rivers and, to a lesser extent, from surface-water sheetflow. Even at a depth of only 3 m below the surface, light levels during the wet season can be as low as 7.7% of surface levels. Light levels at the bottom of the Harbour can be as low as 1% of surface levels during the wet season (Padovan 1997).

In analysing turbidity data from the East Arm Wharf development, Munksgaard (2001) found statistically significant effects of season where turbidity was highest during the wet season. However, the mean change in turbidity was relatively minor: from 4 to 12 NTU over the range of conditions analysed. These differences are much lower than the range typically found in the Harbour, that is, between 1 and 35 NTU (Padovan 1997). It can be concluded that season has only a minor effect on turbidity in the main body of the Harbour. There have been no studies on turbidity in the upper reaches of East Arm and Middle Arm where the Harbour is most affected by freshwater inflows during the wet season. Seasonal effects on turbidity, if present, would most likely be found here (Padovan 2003).

Turbidity levels recorded in the nearshore development area by URS (2009b) were up to 73.6 NTU, with a mean reading of 6.9 NTU. Predictably, higher NTU values were found at the bottom of the water column than at the surface, with higher levels also being recorded in the wet season when compared with the dry season. During ebb tides turbidity levels were higher upstream than in the Harbour; this was reversed during flood tides (see Appendix 9).

Total suspended solids

Measurements of TSS and turbidity both indicate the levels of solids suspended in the water column, whether mineral (e.g. soil particles) or organic (e.g. algae). However, TSS measures an actual weight of material per volume of water, while turbidity, as described above, measures the amount of light scattered.

Water-quality sampling in Darwin Harbour in 2002 and 2003 by the Australian Institute of Marine Science (AIMS) recorded an annual TSS average of 10.3 mg/L, with a minimum of 3.1 mg/L and a maximum of 73.5 mg/L (AIMS 2008). TSS levels around Blaydin Point measured by URS ranged from 1.5 to 83 mg/L, with an average of 15 mg/L. Elevated TSS levels were found to occur in the wet season at the bottom of the water column on a flood tide at all sites. Generally, TSS levels were not as high in Harbour waters as in East Arm and Middle Arm. No clear distinction was found between wet- and dry-season TSS levels at the surface (see Appendix 9).

Nutrients and phytoplankton

Studies on nutrients in the sediments of Darwin Harbour have been few and their scopes have been limited. Padovan (1997, 2002) and Sly, Marshall and Williams (2002) found total nitrogen in the main body of the Harbour to be between 0.2 and 0.6 mg/L. The concentration of total nitrogen in most of the inflowing river waters was similar to that found in the Harbour and therefore wet-season inflows are not expected to affect nitrogen concentrations in the main waterbody (Padovan 1997, 2003).

Phytoplankton is an important water-quality measure as its abundance and composition is directly influenced by environmental factors, including nutrients and light. The abundance of phytoplankton is typically quantified through the enumeration of cell numbers and through the measurement of chlorophyll-*a*, the main light-absorbing pigment used in photosynthesis.

Planktonic organisms, along with mangrove plant and animal communities, can form the basis of the food web in coastal marine ecosystems. About 250 different species of phytoplankton have been found in Darwin Harbour, which is typical of tropical, oceanic waters in northern Australia (WMB 2005). Results from the monitoring study by WMB (2005) demonstrated that for most of the year the amount of phytoplankton in the Harbour was very low (<2 μg/L of chlorophyll-*a*), though some measurements in the Blackmore River were up to ten times higher than this.

No seasonal or inter-annual changes in concentrations of chlorophyll-*a* in the Harbour have been found, though concentrations vary with tide cycle (Padovan 1997, 2002). Concentrations were highest during the midpoint of a spring tide, suggesting the resuspension of algal cells from the bottom. Overall, the concentrations measured in the Harbour are similar to those found in other north Australian waters (Padovan 1997).

Algal blooms, which are symptomatic of excessively nutrient-rich water, have not been recorded in Darwin Harbour (WMB 2005).

3.3.5 Marine sediments

Surface sediments

Michie (1988) divided Darwin Harbour sediments into four types:

- terrigenous gravels, which occur primarily in the main channel
- calcareous sands with greater than 50% biogenic carbonate, which are among or close to the small coral communities at East Point, Lee Point and Channel Island. Carbonate sediments, largely derived from molluscan shell fragments, also occur in spits and shoals close to the Harbour mouth
- terrigenous sands on beaches and spits, with 10–50% carbonate, largely derived from molluscs. This type of sediment is predominantly quartz and clay
- mud and fine sand on broad, gently inclined intertidal mudflats that occur in areas characterised by low current and tidal velocities, such as in Kitchener Bay (prior to the construction of the Darwin City Waterfront).

Soft surfaces with varying amounts of gravel and sand are found in the main channels around reefs, on beaches and on spits and shoals near the mouth of the Harbour. The spatial extent of these surfaces is sometimes difficult to determine because of the gradual transition between muddy, sandy and coarser sediments and sediment movement associated with large tidal influences (Fortune 2006).

The physical and biotic structure of soft substrates is governed by grain size, oxygen state and sediment chemistry. The rate of sediment chemistry processes (e.g. the carbon, nitrogen and sulfur cycles) and the plant and animal composition in and on the sediment are linked (e.g. see Kristensen & Blackburn 1987; Pearson & Rosenberg 1978). However, the extent to which the sediment biogeochemistry determines flora and fauna assemblages, and vice versa, is largely unknown for Darwin Harbour (Smit 2003).

Coarser material appears to be located in the central channels of tributaries and the main body of the Harbour as opposed to the landward margins, demonstrating the influence of tidal movement, bathymetry and potential transport capacity in these regions (Fortune 2006).

In 2008, URS sampled surface marine sediments at 151 sites in the nearshore development area (Figure 3-15) using grab sampling. The surface sediments were analysed for a range of substances: a suite of metals occurring both naturally and as a result of man-made contamination (namely aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver and zinc); tributyltin compounds; nutrients (nitrogen and phosphorus); total organic carbon; total petroleum hydrocarbons; polycyclic aromatic hydrocarbons; and the BTEX compounds. In addition, organochlorine pesticides, polychlorinated biphenyls and radionuclides were investigated at some sites. All surface sediments were also assessed for particle size distribution and for their acid sulfate soil (ASS) potential.

Subsurface sediments (>0.5 m below surface level) were sampled through piston coring and borehole drilling at 18 sites in the nearshore development area during geotechnical investigations (Figure 3-15). The majority of the subsurface sediment samples were only assessed for metals concentrations and ASS potential, as the sampling depth was considered to preclude the possibility of anthropogenic contamination.

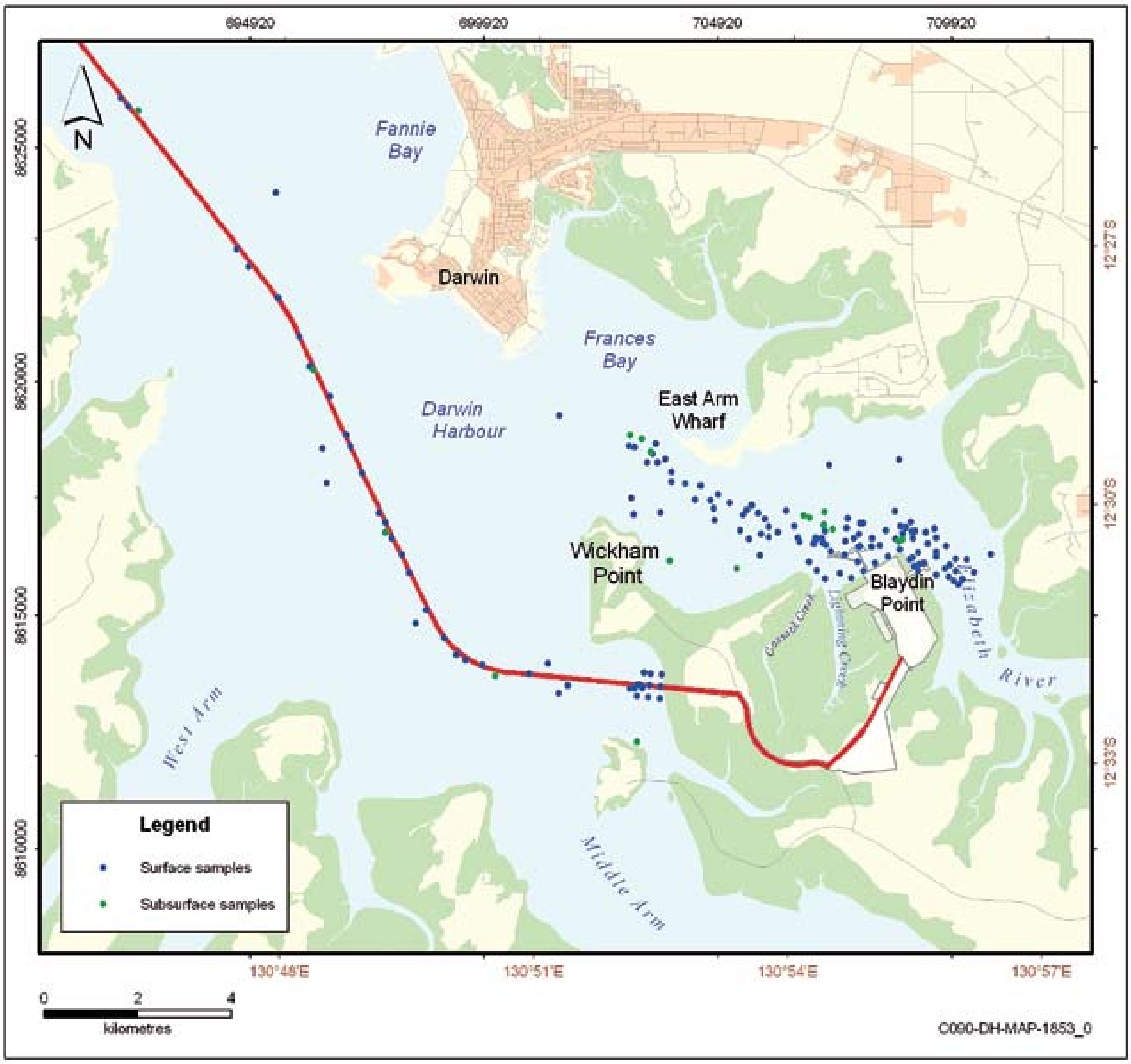


Figure 3-15: Nearshore sediment sampling sites

The sediment quality surveys were undertaken in accordance with the *National ocean disposal guidelines for dredged material* (NODGDM)[4] developed by Environment Australia (2002). These provide "screening level" concentrations for a range of contaminants below which toxic effects on organisms are not expected, as well as "maximum" concentrations at which toxic effects on organisms are probable if the contaminant is in biologically available form.

The results of the URS sediment survey are discussed below, while the full technical report is provided in Appendix 9.

Metals

Sediments play a key role in the geochemical and biological processes of an estuarine ecosystem such as Darwin Harbour. Sediments can act as sinks for metals and organics that enter the Harbour. However, the following physical factors may bring about the exchange of heavy metals between water and sediments:

- hydrodynamic effects that may cause sediment suspension at the sediment–water interface
- bioturbation in sediments that may tend to redistribute heavy metals in the profile
- the salinity of the interstitial water in the sediments (Fortune 2006).

The NODGDM provided guideline concentrations for many heavy metals that could affect environmental health. Previous studies of heavy-metal concentrations in Darwin Harbour sediments (e.g. Currey 1988; Hanley & Caswell 1995; Padovan 2002; Parry & Munksgaard 1995; Peerzada 1988; and Peerzada & Ryan 1987) all recorded levels below the guideline screening levels. More recently, Fortune (2006) undertook a detailed study of heavy-metal concentrations in sediments throughout the Harbour and recorded elevated metals levels at a number of sites. Arsenic was the only metal notably higher in the East Arm area; this, however, is likely to be a consequence of local geology rather than of anthropogenic contamination.

Metals concentrations in surface sediments recorded by URS were fairly consistent across sites throughout East Arm, Middle Arm and the main body of Darwin Harbour. Arsenic concentrations were regularly recorded above NODGDM screening levels (20.0 mg/kg) and occasionally above maximum levels (70.0 mg/kg), both in surface and subsurface sediments. Overall, the mean sediment concentration of arsenic was 34.5 mg/kg. Because of these consistently high arsenic concentrations, further testing was undertaken using a 1-M hydrochloric acid[5] digest. This indicated that only a very small proportion of the arsenic would dissolve into bioavailable forms. Arsenic from sediments is therefore unlikely to be toxic in the marine environment. Its presence in both surface and subsurface layers also suggests that the arsenic occurs naturally in these marine sediments and is not the result of anthropogenic contamination.

Sediment chromium and mercury concentrations were recorded above screening levels at a small number of sites in East Arm (10 for chromium and 2 for mercury, out of 109 sampling sites), and along the pipeline route (4 sites out of 30 for chromium only). Neither was recorded at concentrations above guideline maximum levels and, when averaged across the total samples taken, the resulting mean and 95% upper confidence level (UCL) concentrations for these metals were below the guideline screening levels. No further testing (e.g. for bioavailability) was warranted, in accordance with guideline protocols. Whether these slightly elevated metals levels are a result of anthropogenic pollution is unknown and the marine sediments are not considered "contaminated" based on these occasional deviations from guideline screening levels.

Hydrocarbons

Potential sources of hydrocarbons around Darwin Harbour include those listed below:

- seasonal stormwater inflow from Darwin and Palmerston stormwater drainage networks
- the Naval Fuel Installation at Stokes Hill
- the former fuel storage at the Channel Island Power Station
- the bulk hydrocarbon storage at East Arm Wharf
- the bulk hydrocarbon storage at the Darwin LNG plant
- inventories in recreational and commercial vessels and ships.

4 The *National ocean disposal guidelines for dredged material* (Environment Australia 2002) were formally replaced by the *National assessment guidelines for dredging 2009* (DEWHA 2009b) in May 2009, although the two sets of guidelines are very similar. The marine sediments study was completed in 2008 and referenced the NODGDM.

5 A 1-M (one molar) solution contains one mole of solute per litre of solution.

A survey by URS (2004) sampled 12 sites around the Darwin Wharf Precinct and at one reference site in the Elizabeth River approximately 6 km upstream of East Arm Wharf. The highest concentrations of petroleum hydrocarbons (11–16 mg/kg) were found at sites in Kitchener Bay, Fort Hill Wharf and landward of the Iron Ore Wharf. Concentrations at the remaining sites were between 6 and 10 mg/kg. Petroleum hydrocarbons were also present at the reference site, though the concentration (4.9 mg/kg) was lower than in any of the samples from the Darwin Wharf Precinct sites.

Petroleum hydrocarbons were assessed in surface sediments at 151 sites in the sampling program for the nearshore development area. In the majority of samples, including all samples near the pipeline shore crossing, hydrocarbons were not recorded above the minimum laboratory detection limit.

In East Arm, petroleum hydrocarbons were recorded with maxima of 10 mg/kg for the C_{10}–C_{14} hydrocarbon fraction, 42 mg/kg for the C_{15}–C_{28} fraction, and 24 mg/kg for the C_{29}–C_{36} fraction. Similar results were recorded at sites along the proposed pipeline route, with maxima of 5 mg/kg for the C_{10}–C_{14} hydrocarbon fraction, 31 mg/kg for the C_{15}–C_{28} fraction and 31 mg/kg for the C_{29}–C_{36} fraction (see Appendix 9). Total petroleum hydrocarbon concentrations were well below the screening level of 550 mg/kg given in the *National assessment guidelines for dredging 2009* (DEWHA 2009b), and are likely to be the result of historical industrial and port operations around East Arm.

The BTEX compounds were not recorded above laboratory detection limits at any site. Polycyclic aromatic hydrocarbons were recorded below laboratory detection limits at 103 out of 109 sites, and where detectable concentrations were recorded these were well below guideline screening levels (see Appendix 9).

Tributyltin

Tributyltin compounds (TBTs) are chemicals that contain the $(C_4H_9)_3Sn$ group; they form the main active ingredients in broad-spectrum biocides. In the late 1960s, TBTs, especially tributyltin oxide, came into widespread use as antifoulant additives to marine paints applied to the hulls of vessels. The leaching of TBT from the paint was effective in preventing the growth of fouling organisms on hulls, but also had detrimental environmental effects on biota in the surrounding waters. These compounds are persistent organic pollutants that biomagnify up the marine food chain and also tend to accumulate in sedimentary environments, particularly in fine sediments. In port sediments, TBTs are typically associated with paint flakes, which may be dislodged from vessel hulls during berthing or while alongside wharves.

In 1999, the International Maritime Organization initiated the development of a legally binding instrument to address the harmful effects of antifouling systems used on ships throughout the world. That instrument, the International Convention on the Control of Harmful Anti-fouling Systems on Ships, was adopted in 2001 and entered into force in September 2008. Australia became a party to the Convention in January 2007 and the Commonwealth Government has reinforced its commitment to the control of harmful antifouling compounds by passing the *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth) which also came into force in September 2008. The Convention prohibits the use of harmful organotins in antifouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in antifouling systems.

A survey of marine sediment quality by URS (2004) found that there were elevated levels of TBTs across Darwin Harbour. However, although they were detected at most sites, the guideline screening level for TBT (5 ng/g) was exceeded at only one location—Fort Hill Wharf, which has received large numbers of vessels since the late 1960s.

Recent sampling of marine sediments in the nearshore development area did not record TBTs above the laboratory detection limit at any of the sampling sites (see Appendix 9).

Total organic carbon

Total organic carbon has a major influence on both the chemical and biological processes that take place in sediments. At very low total organic carbon levels, little food is available for consumers, resulting in a low-biomass community. At very high total organic carbon levels, enhanced sediment respiration rates lead to oxygen depletion and accumulation of potentially toxic reduced chemicals. Hyland et al. (2000) found that total organic carbon levels below 0.05% w/w (0.5 mg/g) and above 3.0% w/w (30 mg/g) were related to decreased benthic abundance and biomass.

Total organic carbon levels recorded in the nearshore development area averaged 0.3% w/w (3 mg/g) in East Arm and the main body of the Harbour, and 0.5% w/w (5 mg/g) in Middle Arm at the pipeline shore crossing (see Appendix 9). These levels are within the range supporting normal biomass growth.

Nutrients

Nitrogen and phosphorus are major plant nutrients and their availability in marine systems most often determines the limits on plant growth. An overabundance of bioavailable nitrogen and phosphorus can lead to the eutrophication of waterways and the proliferation of macroalgae and phytoplankton, which can choke estuaries and other confined marine systems. Large quantities of these nutrients can be held in sediments, mostly in non-bioavailable forms.

During sediment sampling in the nearshore development area, concentrations of nitrogen as nitrite and nitrate (a measure of soluble, oxidised forms of nitrogen) were recorded at very low levels throughout the Harbour (0.28 mg/kg along the pipeline route, and less than 0.1 mg/kg in East Arm and Middle Arm). Soluble nitrogen is therefore considered to form an insignificant portion of the total nitrogen pool (see Appendix 9).

Average total nitrogen concentrations of 581 mg/kg and 356 mg/kg were recorded in the main body of the Harbour (the proposed pipeline route) and in East Arm respectively. Mean total phosphorus levels ranged from 315 mg/kg in the main body of the Harbour to 509 mg/kg in East Arm, which is within the range of that reported by Parry et al. (2002) in a similar study. Total sulfur, another essential plant nutrient, was recorded at concentrations ranging from 0.18% to 0.8% (see Appendix 9). No guideline criteria are available for sediment nutrient levels.

Particle size distribution

Fortune (2006) reported on a sediment grain-size study that included 29 sampling sites extending from the main port area of the Harbour through to the upper reaches of the Elizabeth River. This work was conducted in 1993 prior to the infrastructure development and dredging at the East Arm Wharf facility, with sampling effort concentrated in this area (Fortune 2006). Sediment distribution in the area largely comprised coarse- to fine-grained sand (62–500 µm) with a variable distribution of granules and the finer fractions (silt and clay) among sites. Silt constituted no more than 13% of the samples in those sites in the East Arm section and the finer clay fraction constituted no more than 4.5% by weight for all sites sampled.

Sampling in the East Arm portion of the nearshore development area yielded similar results, with an average clay and silt content of 16.5% across 109 samples. Surface sediments in the main channel area were generally made up of larger-grained sediments such as fine sand, coarse sand and shell fragments. Sediments were finer closer to the shores of Blaydin Point, with higher proportions of silts and fine sands (see Appendix 9).

Surface sediments in the main body of Darwin Harbour (along the pipeline route) were generally fairly coarse, with a silt and clay content of 19.0%. In contrast, surface sediments around the pipeline shore crossing were much finer, with clay and silt accounting for 37.4% of the sample weights and fine sand (<250 µm) contributing a further 51.5%.

Acid sulfate soil potential

Sediments in the nearshore development area were analysed for their potential to oxidise to produce sulfuric acid, as well as for their capacity (in conjunction with sea water) to prevent the formation of acid through neutralisation by carbonaceous sediment or alkaline water. Methods used to assess ASS potential included both the suspension peroxide oxidation combined acidity and sulfate (SPOCAS) and the chromium suites of tests. The ASS risks in the sediments were then screened using texture-based criteria and then a site-specific ASS risk matrix was developed for the nearshore development area. These assessment methods are described in detail in Appendix 9.

Potential ASS risk was identified at a number of sites throughout the nearshore development area, including 54 sample sites in East Arm, eight along the pipeline route and one at the pipeline shore crossing. Oxidisable sulfur contents were recorded at <0.02–1.5% sulfur and acid neutralisation capacities were measured at 0.06–54.4% sulfur equivalent. Sites of potential ASS risk are spread fairly evenly throughout shallow shoreline and deeper channel areas of the survey area (see Appendix 9).

Subsurface sediments

Coffey Geotechnics Pty Ltd (Coffey) conducted geotechnical and geophysical investigations in the nearshore development area in 2008 by drilling a total of 29 boreholes. The major geological units identified in the area are described in Table 3-6.

Table 3-6: Geological units identified in the nearshore development area

Stratigraphic order	Unit	Name	Age	Material description
Recent marine	1a	Channel deposits	Recent/Quaternary	Mainly sands with some silts, clays and gravels.
	1b	Mangrove muds	Recent/Quaternary	Mainly silts and clays with some sands, locally organic and/or calcareous. Marine and intertidal alluvium adjacent to mangrove swamps.
	1c	Channel lag deposits	Recent/Quaternary	Mainly gravels and clayey gravels at base of live and historical channel.
	1d	Coral	Recent/Quaternary	Live coral.
	1e	Lateritic/colluvial soils	Tertiary/Quaternary	Lateritic/colluvial material (clay, sand, silt and gravel).
Burrell Creek Formation	2ai	Phyllites and sandstones (residual soils)	Early Proterozoic	Residual soils derived from sandstones and phyllites of the Burrell Creek Formation (silts and clays with some sands and gravels).
	2aii	Phyllites and sandstones (weak, extremely weathered rock)	Early Proterozoic	Extremely to very low-strength weathered sandstones and phyllite of the Burrell Creek Formation.
	2aiii	Phyllites and sandstones (rock)	Early Proterozoic	Competent phyllites and sandstones (generally low strength or greater) of the Burrell Creek Formation.
	2b	Conglomerate	Early Proterozoic	High-strength conglomerate of the Burrell Creek Formation, possibly an ancient debris flow.
Undifferentiated granite	3	Weathered granodiorite	Early Proterozoic	Weathered granodiorite/granite.

Source: Coffey 2009.

Sediments in East Arm to the north of Blaydin Point generally show several metres' thickness of unconsolidated sediments overlying the phyllites and sandstone of the Burrell Creek Formation (Coffey 2009). The upper 5–15 m of the phyllites are weathered in some areas while unconsolidated recent sediments directly overlie competent phyllite and sandstone rock in other areas.

To the east of Blaydin Point there are several metres of unconsolidated recent muds and channel lag deposits lying over 20–25 m of weathered phyllite and residual soils (Coffey 2009).

The predominant seabed material to the west of Middle Arm Peninsula, near the pipeline shore crossing, is residual soil grading to weathered phyllite and sandstone. There are also pockets and veneers of unconsolidated sands and gravels and harder phyllite (Coffey 2009).

Metals levels recorded in subsurface sediment quality sampling were consistently lower than the guideline screening levels, except for arsenic at a number of sites. Sediment arsenic was found not to be bioavailable to any significant extent and its presence in subsurface sediment indicates that these elevated concentrations are attributable to local geology rather than to anthropogenic contamination (see Appendix 9).

Nickel was also recorded just above the screening level concentration in one subsurface sediment sample in East Arm, but well below the maximum level. This single elevated sample can be considered an anomaly in the context of the overall sampling program, and its origin is unknown.

A number of subsurface sediment samples were classified with potential ASS risk, including six samples in East Arm, one on the pipeline route and three at the pipeline shore crossing. Oxidisable sulfur contents were recorded at <0.02–3.52% sulfur and acid neutralisation capacities were measured at 0.10–18.6% sulfur equivalent. Sites of potential ASS risk were located in both shallow shoreline and deeper channel areas of the survey area (see Appendix 9).

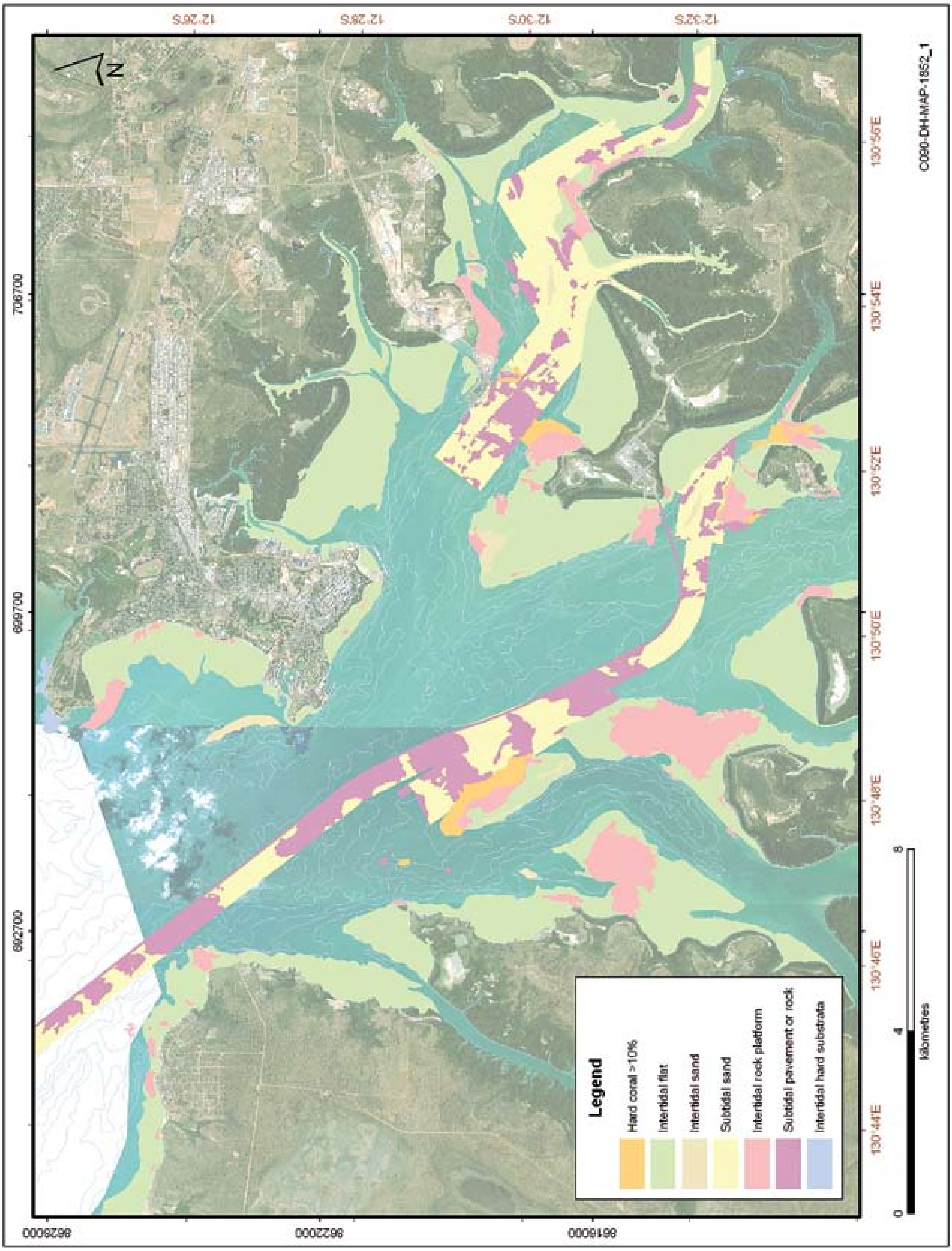


Figure 3-16: Marine habitats in Darwin Harbour

3.3.6 Marine communities

Darwin Harbour has a complex assemblage of marine habitats (Figure 3-16) and there are large differences in the extent, diversity and significance of the biological communities inhabiting them. Rocky intertidal areas are found where headlands protrude into the Harbour. Extensive mangrove communities dominate in the bays and other protected areas throughout the intertidal zone. Seaward of the mangroves, extensive flats occur in the lower intertidal zone. Many of these flats are mud, but some areas are basement rock that may have thin covering layers of sand or mud.

The sides of the main drainage channels are generally rocky, but the bottoms are similar to the intertidal areas in that they vary from exposed pavement, through sand-veneered pavement, to beds of sediment which vary from gravel to fine sands and silt.

The numbers of known species in the major marine taxonomic groups in the Harbour have been presented by McKinnon et al. (2006), as shown in Table 3-7. The major marine communities present in the Harbour are described further in this section. It should be emphasised that the marine environment in the Harbour is complex, and many habitats are present as small units on a single shoreline, with diverse patterns of habitats such as rocky shores, mangroves and mudflats all occurring in a small area.

Table 3-7: Number of marine species per major animal and plant group in the Darwin Harbour region

Taxonomic group	Number of species	Comments
Hard corals	123	–
Soft coral and sea whips	50–65	–
Sponges	56	Only approximately 10% of the sponge fauna has been described.
Algae	110	These numbers represent only macroalgae.
Seagrasses	3	–
Hydroids	63	–
Polychaetes	600+	Highest diversity on subtidal reefs.
Crustaceans	1000+	Estimated number of species.
Molluscs	924	–
Echinoderms	60–117	–
Fish	415	–

Source: McKinnon et al. 2006.

The taxonomic groups and marine communities described in this section are well represented throughout the coastal environments of the Anson–Beagle Bioregion. For example, in the Fog Bay – Bynoe Harbour region, located approximately 35–60 km south-west of Darwin, habitats were identified through satellite and aerial photography and underwater video by NRETAS (2007c). The project revealed a range of different environments including reefs, intertidal flats, subtidal flats, seagrass meadows and associated marine communities. Coral reef assemblages were generally found on fringing and subtidal rocky reefs with low turbidity and relatively good light levels. In high turbidity, algal and sponge communities dominated. More than 200 species of fish were collected; approximately 87 of these did not occur in the embayment of Darwin Harbour. Endangered green sawfish (*Pristis zijsron*) were also found on muddy bottoms in the southern Fog Bay area.

The following sections describe the dominant marine communities in the nearshore marine environment.

Rocky shore communities

Hard substrates in the Harbour consist of coastal cliffs and cliff talus, rocky platforms and rock bars. Weathered and lateritised sandstones and conglomerates form the majority of intertidal rocky platforms (e.g. Weed Reef and Channel Island Reef), intertidal rocky outcrops (e.g. north of Middle Point), subtidal rocky outcrops (e.g. Plater Rock and Stevens Rock) and rock bars in the upper reaches and mouths of Darwin Harbour's tributaries (Smit 2003).

The general zonation of hard substrates in the Harbour has been described by Pope (1967), Ferns (1996), Russell and Hewitt (2000) and some environmental impact assessments for proposed developments. Zonation patterns on the shores can be readily seen, with relatively few species occurring in the upper intertidal zone where organisms are exposed to variable conditions of temperature, sunlight, salinity and other factors that can change suddenly as storms pass through the area during the wet season. Diversity increases further down the shore where conditions are not as extreme (URS 2002).

Intertidal zonation is mostly determined by the period of exposure between high and low tides. In the upper to mid-intertidal zone (above mean sea level), oysters and barnacles are the most abundant faunal groups on the exposed rock, whereas small molluscs (*Nerita* spp. and *Thais* spp.) and isopod crustaceans seek refuge in the more protected areas (e.g. crevices, holes and under rocks). Below the high intertidal zone, approximately at mean sea level, cyanobacteria (blue-green algae) and diatoms form a dark band across the rock bed.

The lower intertidal can be divided into two zones:

- upper zone: mainly bare rock dominated by oysters, limpets, barnacles, chitons, soft corals (*Sinularia* spp., *Sarcophyton* spp. and *Lobophytum* spp.), sponges (*Dysidea* spp.), turf algae and brown algae (*Padina* spp.)
- lower zone: forming the intertidal–subtidal interface, generally represented by those species that are found in subtidal waters. Here, the rock substrate can be covered with hard and soft corals, sponges, crustaceans, anemones and many species of macroalgae (Smit 2003).

Hard-coral communities

Coral-dominated communities in Darwin Harbour are located in lower intertidal to high subtidal areas to depths of 5–10 m below LAT. These areas are characterised by strong currents where the sediment load is kept in suspension and light intensity does not fall below a minimum value for coral and algal survival. Species living in Darwin Harbour are tolerant of conditions—such as variable salinity, high turbidity and sedimentation—that exclude most corals. The corals in the intertidal zone can be exposed to the air during afternoon low-tide periods in the hottest and wettest months of the year (December to February), which renders them vulnerable to desiccation and to freshwater impacts from rainfall, leading to stress, bleaching and mortality. Known localities of coral-dominated communities are Channel Island, Weed Reef, north-east Wickham Point and South Shell Island.

Mass spawning of hard-coral communities in the Harbour is not known to have been observed, although many of the species present are those that reproduce by spawning (i.e. the release of male and female gametes into the water column). Observations in other areas around the world indicate that coral spawning on most reefs extends over a few months during the breeding period, typically between late spring and autumn (Stoddart & Gilmour 2005). Spawning of corals in the Northern Territory Aquarium has been observed around the full-moon period in October and November (TWP 2006). In Northern Queensland, captive corals have been observed to spawn at the same time as those in the adjacent waters.

A comparative assessment of six potential coral sites was undertaken by URS in August 2008: these were Channel Island, South Shell Island, Walker Shoal, Weed Reef, and two sites to the north of Blaydin Point. These assessments were conducted through diving and ROV surveys (URS 2009c, provided as Appendix 8 to this Draft EIS).

A total of 44 species of hard coral was recorded at the six sites. The area covered at each location was approximately 1000 m^2 and only a limited time was available to conduct a full census of the species present. Wolstenholme, Dinesen and Alderslade (1997) reported finding 123 species of hard corals in Darwin Harbour using three divers over ten dives. The results of the survey by URS were broadly consistent with those of the 1997 survey, taking into account the reduced effort.

The Channel Island coral community had the highest percentage cover, species richness (29 species) and diversity of hard corals of all sites. The South Shell Island site and the Weed Reef site had similar cover, diversity and species richness (21 and 22 species respectively), albeit with some differences in species composition. Nine species of hard coral were recorded at the two Blaydin Point sites. No corals were recorded at Walker Shoal.

The rock platform at Channel Island was found to have the most developed hard-coral community of all the sites surveyed. The upper crest and top of the platform (approximately 0 m LAT) was dominated by massive faviid corals, showing clear signs of exposure to air during extreme low tides. These corals were up to 2 m in diameter, with a ring of living tissue approximately 20–30 cm wide around the circumference and dead coral in the middle. Hard-coral cover on the top of the platform was estimated to be approximately 20% of the total area.

The slope at Channel Island (approximately 0.5–1.5 m below LAT) was dominated by *Mycedium elephantotus*, with colonies up to 4 m across. Hard-coral cover in this zone was estimated to be approximately 25–30%. Below the slope (deeper than approximately 1.5 m below LAT), a soft-bottom community of sponges, soft corals, sea whips and sea fans was present. Occasional hard corals were found in this zone, primarily *Goniopora* species. Hard-coral cover in this zone was estimated to be approximately 5%.

South Shell Island was found to have a well-developed hard-coral community on the slope (approximately 0–1.5 m below LAT) with an estimated 15–20% cover of hard corals. Faviids were the dominant corals, although there were numerous *Turbinaria peltata* colonies. Sponges, soft corals and hydroids were numerous on the slope, and were dominant at the base of the slope (deeper than approximately 1.5 m below LAT) along with sea whips, sea fans and feather stars.

The top of Walker Shoal (6 m below LAT) was found to be devoid of hard corals, with biota dominated by gorgonians and sponges (see Appendix 8).

Communities dominated by soft corals and sponges

Previous studies have shown that Darwin Harbour has a relatively low diversity of soft corals and sea whips, with 20–25 species (11 genera) and 30–40 species (18 genera) respectively. Their poor representation can be attributed to the turbidity of the water in the Harbour and to the combination of factors such as sedimentation, light availability, wave and flow exposure and steepness of reefs that control the abundance of soft corals (Fabricius & Alderslade 2001).

Generally, sea whips and sea fans are restricted to current-exposed but wave-protected habitats. Most species require hard substrate for larvae to settle. However, some species have colonised soft-bottom substrates with rootlike structures. These either aggregate gravel with their roots to form a suitable substrate for attachment or dig into the sediment (e.g. sea pens) (Smit 2003).

Sponge-dominated communities occur in areas where hard substrate is available and coral-dominated communities cannot establish. These habitats can occur at any depth in the lower intertidal and subtidal areas. They are patchy by nature and often form a transition zone between hard substrates and the subtidal mud-dominated substrates. Substrates dominated by gravel and/or shell grit or sand–silt are the most favourable to sponge larval settlement. Many species of sponge that do prefer soft substrates are often submersed in the sediment (Smit 2003).

Sponge-dominated communities also contain a wide range of other organisms, including bryozoans, sea squirts, and hydroids (Smit 2003). Very little information is available on these organisms in the Harbour. As with sponges, bryozoans prefer hard substrates and are the most abundant encrusting fauna on wharf pilings. When bryozoans are encountered on soft substrates these substrates tend to be unsorted coarse-grained sediments. This may be because bryozoans are one of the first groups of organisms to colonise gravelly and hard substrates (Smit 2003; Smit, Billyard & Ferns 2000). Hydroids also require a substrate for attachment, even if this is only a small pebble or fragment of shell grit (Smit 2003).

In order to characterise the marine habitats in the nearshore development area, URS conducted drop-camera, ROV and diving surveys on a number of seabed features including wrecks and rocky areas. The results of these surveys (URS 2009c) are summarised here and are presented in full in Appendix 8.

The wrecks of the *Kelat* coal barge and five Catalinas (World War II flying boats) near Blaydin Point and the wreck of the SS *Ellengowan* to the north of Channel Island all supported heavy growths of soft corals, sponges, bryozoans, hydroids and sea squirts, with a sparse occurrence (where present) of solitary hard corals. Pelagic fish life was moderate to abundant at these sites and consisted of *Protonibea diacanthus* (black jewfish), *Platycephalus* spp. (flatheads), *Synanceia verrucosa* (stonefish), and various stingarees (rays of the family Urolophidae), as well as a small number of sharks. Other features investigated were old mooring blocks—either concrete-filled sea containers or plain concrete blocks. These had a sparse cover of plants and animals and low numbers of fish (URS 2009c).

Macroalgae

Macroalga-dominated communities in the Harbour are often located on platform crests and in the intertidal–subtidal interface zone, generally a few metres either side of the low-water mark and often in association with coral- or sponge-dominated communities. Algal composition is highly seasonal and seems to be regulated by the amount of time the community is exposed during spring low tides. During the build-up season (October to December) when the tidal range is at its largest and the extreme spring low tides occur in the middle of the day, the larger macroalgae die back and turf algae dominates. During the dry season, when the tidal range is not so extreme, the larger macroalgae are more prolific. Known localities of these communities are East Point Reef and Weed Reef (Smit 2003).

Marine habitat investigations by URS (see Appendix 8) recorded a sparse though diverse macroalgal community on the rubble-covered pavement at Weed Reef, which included browns (*Sargassum* and *Padina* spp.), foliose reds (*Laurencia* spp.), greens (*Caulerpa*, *Ulva* and *Udotea* spp.) and calcareous greens (*Halimeda* spp.).

Seagrass meadows

Significant seagrass beds are not known to occur in Darwin Harbour and were not recorded in habitat surveys around Blaydin Point. Over the broad areas of sand-veneered pavement at Weed Reef, a very sparse, patchy coverage of a seagrass (*Halophila* sp.) was recorded in baseline surveys for the Project (see Appendix 8). Sparse *Halodule uninervis* and *Halophila decipiens* were also recorded at Wickham Point during baseline surveys for the Darwin LNG Plant (Dames & Moore 1997). Seagrass was not recorded in targeted habitat surveys completed by Whiting (2004) at the reef flat at Channel Island, nor in surveys there by URS.

Immediately outside the Harbour a large seagrass meadow has been described at Casuarina Beach south of Lee Point, extending up to 2.5 km offshore. A variety of seagrass species have been recorded in this area, including *Cymodocea rotundata*, *Halophila ovalis*, *Halophila decipiens* and *Halodule uninervis*. (N. Smit, Marine Biodiversity Group, NRETAS, pers. comm. July 2009).

Soft sediment communities

Even though the spatial extent of marine habitats has not been fully mapped, it is estimated that soft substrates cover approximately 80% of the available substrates in the Darwin Harbour region (McKinnon et al. 2006). Soft substrates consist mainly of muds and fine sand and are found in front of (seaward of) mangroves and in intertidal and subtidal areas between the hard substrates and the main drainage channels.

Intertidal soft substrates mainly consist of muddy to sandy-mud substrates. At first sight they appear to be desert-like, but in fact they support infauna communities dominated by polychaete worms. These substrates generally support communities with low species diversity but high numbers of a particular species. This intertidal substrate is important for feeding by shorebirds during low tides. On the incoming tide many fish migrate with the tide to the higher intertidal areas also to feed on invertebrates living in and on the substrate (Smit 2003).

Subtidal soft-substrate communities are far more diverse than their intertidal counterparts. Marine worms, crustaceans, echinoderms and sponges dominate and they play an important role in the ecological food chain in the Harbour. This substrate consists of varying degrees of mud and sand fractions and ultimately grades into the coarser sediments in the channel (Smit 2003).

There are approximately 600 species of polychaete worms in the Harbour, although only a small percentage has been scientifically described. Polychaetes are found over a wide variety of habitats, but have a preference for fine-grained, sandy and unsorted sediments (Smit, Billyard & Ferns 2000).

The crustacean fauna of Darwin Harbour is typical for northern Australian waters and is dominated by Indo-West Pacific species. The total number of crustacean species throughout the region is thought to be about 1000. It is estimated that there are probably 40–60 species of crabs associated with mangroves in Darwin Harbour. Crustaceans are a diverse group and the many species have different niches in the broad range of marine environments. Consequently, it is difficult to determine which habitats have more species than others (Smit, Billyard & Ferns 2000).

Darwin Harbour is the best-collected locality for marine molluscs in northern Australia. The Museum and Art Gallery of the Northern Territory has compiled a mollusc catalogue for Darwin Harbour which lists 924 species, including 75 associated with mangrove communities. Molluscs are found in a wide range of habitats with many species occupying a specific niche (Smit 2003).

In order to characterise the benthic fauna present in the nearshore development area, sediment samples were analysed by URS in June 2008. The diversity of major taxonomic groups ranged between six and 11 groups at each site, with a total of 17 families of infauna recorded. Amphipods were the most abundant taxon (30% of the total), with polychaetes the second most abundant (27% of the total) (see Appendix 8).

There was a sparse biota in the soft sediments at all sites along the gas export pipeline route within Darwin Harbour, including occasional sea whips, hydroids, sea pens, sponges and sea squirts with low bioturbation (around 10 burrows per square metre) (Figure 3-17).

Source: URS 2009c.

Figure 3-17: Sand, silt and shell fragment substrate with low bioturbation along the gas export pipeline route in Darwin Harbour

Mangrove communities

The intertidal mudflats around Darwin Harbour support extensive tracts of mangroves. This vegetation type is known for species richness, both in terms of the plant species present and the invertebrate fauna that is associated with it. The mangroves around the Harbour and in particular at Blaydin Point are described in Section 3.4.8 *Vegetation communities*, while the invertebrate fauna is discussed in Section 3.4.14 *Blaydin Point invertebrate fauna*.

Fish

Darwin Harbour waters support an abundance of both resident benthic and transient pelagic fish species. The most recent survey of fishes in the Harbour was undertaken by Larson and Williams (1997), which documented a total of 415 species including 31 new records for the Northern Territory. However, very little is known about their basic requirements, such as habitat preference, food habits, places and times of breeding, and lifespan (Larson 2003).

Fish occupy a wide range of habitats in the Harbour catchment. Most species are small, and are difficult to distinguish taxonomically. The most diverse group in the Harbour area is the gobies (approximately 70 species). The next most diverse group is the cardinal fish (20 species) and, unusually for the tropics, the third most species-rich group is the pipefishes (19 species) (Larson 2003).

Mangroves provide habitat for juveniles of most of the fish species commonly harvested by recreational and Aboriginal fishers, such as trevallies (*Caranx* spp.), mackerel (*Scomberomorus semifasciatus*), salmon (*Eleutheronema tetradactylum* and *Polydactylus macrochir*), grunter (*Pomadasys kaakan*) and barramundi (*Lates calcarifer)* (McKinnon et al. 2006). The Darwin Harbour Mangrove Productivity Study found that during high spring tides the mangrove forest is used extensively by a wide range of fish. At low tide, only resident species appear to remain in pools (Martin 2003).

Barramundi is a particularly important commercial and recreational species in the Northern Territory. Commercial fishing of barramundi is not permitted in Darwin Harbour, nor at Shoal Bay to the north of the Harbour (DoR 2009c). Barramundi spawning occurs at river mouths between the months of September and March, when eggs and larval fish are carried by tides into supralittoral swamps at the salt- and freshwater interface, at or near the upper high-water level. The nearest such swamp systems to Darwin Harbour are located in Shoal Bay in the upper reaches of the Howard River. These swamps are vegetated by seasonal plants, including saltwater grasses and various sedges, and provide nursery habitat for the young fish. The swamps are very productive, providing barramundi with conditions for rapid growth and with shelter from predators (Allsop et al. 2003; URS 2001). The Darwin Harbour barramundi stock most likely spawns in Shoal Bay as there is very little suitable nursery habitat in Darwin Harbour (URS 2001).

Towards the end of the wet season, before the swamps dry out, the juvenile fish move out into adjacent rivers or creeks and usually migrate upstream into permanent fresh waters. If they do not have access to fresh water, they may remain in coastal and estuarine areas (Pender & Griffin 1996). After three to five years, most of the freshwater barramundi migrate back to the ocean to spawn at the beginning of the wet season (Allsop et al. 2003).

Jellyfish

Jellyfish have received little attention and are poorly described for the Darwin Harbour area. Several species of jellyfish and two species of box jellyfish appear to be abundant during the wet season (Grey 1978). It is believed that around the end of the wet season the jellyfish migrate into tidal creeks and produce polyps that attach themselves to submerged mangrove roots. When the water temperature begins to increase towards the wet season, the polyps release and grow and are carried out of the creeks by the increased runoff (Smit 2003).

Significant marine communities

The small coral community on the rocky platform at Channel Island has been considered a unique feature in Darwin Harbour, supporting relatively diverse coral, fish and invertebrate assemblages. The Channel Island coral community is listed on the Register of the National Estate (DEWHA 2009c) and is a declared Heritage Place under the *Heritage Conservation Act* (NT). The declaration is based upon the presence of a relatively diverse community, which demonstrates that a coral-based community can survive in an area where most physical conditions are adverse (e.g. high turbidity, strong tidal currents, and seasonally low salinity). The communities also have a high diversity of coral not consistent with their location in an area of deep, fine muds, and very low salinity and high turbidity during the wet season. The high coral diversity, clear reef zonation and the accessibility of the location make the Channel Island coral community important for research and education (DEWHA 2009c).

3.3.7 Marine habitats of the nearshore development area

This section describes the physical and biological features of the marine habitats in areas that are within, or close to, the disturbance footprint of the Ichthys Project at Blaydin Point, Wickham Point, and along the pipeline corridor (near the alignment of the existing Bayu–Undan Gas Pipeline). A full description of Ichthys Project infrastructure is provided in Chapter 4. These marine habitat descriptions were developed by URS during drop-camera, ROV and diving investigations in 2008 (Figure 3-18) (see Appendix 8).

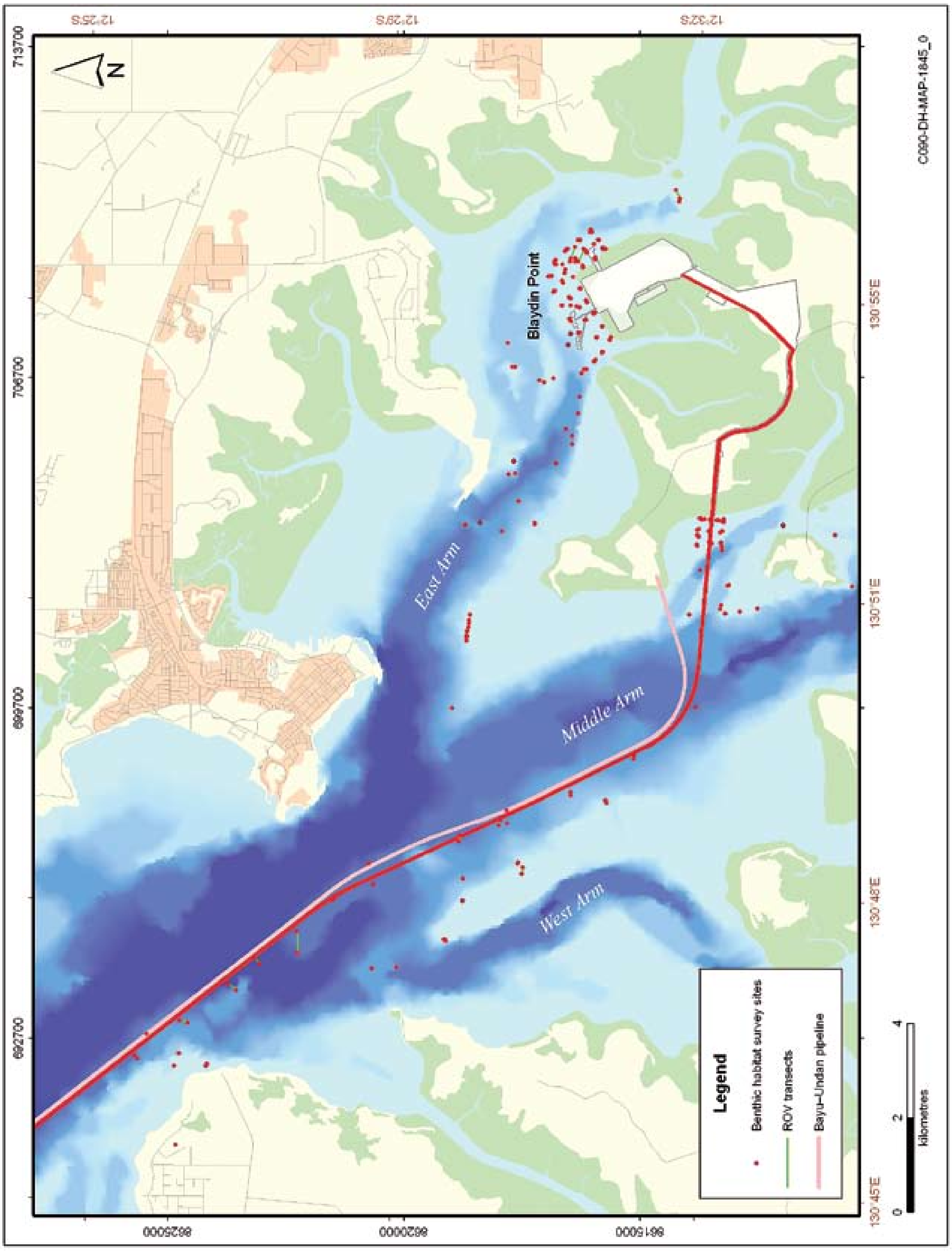


Figure 3-18: Marine benthic habitat survey sites in the nearshore development area

Blaydin Point

Mangroves fringe the greater part of the shoreline of Blaydin Point, becoming less abundant towards the northern point and with a small area at the very north-eastern tip that is devoid of mangroves. In this area sloping rock platforms extend from the shore in northerly and easterly directions. This intertidal platform is an exposed pavement with veneers of coarse sand and silts, gravel, rubble and some larger rocks, with low biota cover present in the northern and western areas (see Appendix 8).

Mangrove mud characterised the greater part of the rest of the mid- to nearshore area surveyed. In general, moderate bioturbation was evident (20 burrows per square metre) with fiddler crabs (*Uca* spp.), alpheid shrimps and mudskippers (*Periophthalmus* spp.) associated with many of the burrows.

In the deeper subtidal area (approximately 1500 m from the shoreline), a low to moderate faunal cover was recorded. This consisted of soft corals (mainly *Sarcophyton* spp. and *Dendronephthya* spp.) where hard substrate was present, together with zoanthids, sponges (laminar, digitate and barrel), bryozoans, hydroids and sea squirts. At deeper sites where hard pavement was not exposed, the faunal community was typically made up of sea fans, sea whips, sea pens and large sponges.

An area of subtidal hard pavement is located approximately 2 km to the north-west of Blaydin Point. The platform, at approximately 0 m LAT, was dominated by green algae with sponges, soft corals, sea whips, sea fans, and limited live coral cover (5%). The slope from 0 m LAT to 1.5 m below LAT supported soft corals, sponges and live hard coral cover (10%) consisting mostly of *Turbinaria peltata*, *Mycedium elephantotus* and several species of faviids. At the base of the slope (deeper than 1.5 m below LAT), a soft bottom with a well-developed community of sponges, soft corals, sea fans and sea whips occurred, with numerous synaptid holothurians (sea cucumbers). This site is considered similar in structure and ecology to other hard-pavement areas in Darwin Harbour and contains benthic species that are widely distributed throughout the Harbour.

Wickham Point

A rock platform extends to the north of Wickham Point (i.e. north of the existing Darwin LNG plant). The eastern edge of this rock platform supports a 10–15% cover of hard coral dominated by laminar *Turbinaria* and *Goniopora* with lower numbers of *Mycedium* spp., faviids and small branching *Acropora* spp., together with soft corals (*Dendronephthya* spp.), sea fans and sea whips. The northern edge of the platform supports a distinctly different assemblage, where the deeper areas consist of coarse sand with sand-wave formations and there are patches of rubble at shallower depths that are dominated by algae and hydroids (see Appendix 8).

Veneers of fine sand and silts were recorded to the east of Wickham Point. All surveyed sites resembled the nearshore sites of Blaydin Point, with low bioturbation (around 10 burrows per square metre) and a low abundance of animals and plants, typically consisting of sea whips and algal turfs.

To the south of Wickham Point, a sparse epibenthic biota and relatively featureless mangrove muds characterised the nearshore intertidal zone. Low to moderate bioturbation was recorded (10–20 burrows per square metre) in a light brown silt veneer overlying a grey fine sand and silt matrix. No epibenthic plants or animals were observed at any of the 12 sites surveyed.

Bayu–Undan Gas Pipeline

The rock armour covering the existing Bayu–Undan Gas Pipeline in Darwin Harbour provides habitat for an abundance of soft corals, sea fans, sea whips, algae and hydroids, with less than 5% hard-coral coverage (Figure 3-19). A moderately rich fish fauna is also found along the pipeline, the most noticeable being members of the family Acanthuridae (surgeon fish). The surrounding sand- and silt-covered seabed supported a sparse coverage of sea whips and sea pens.

Along those parts of the pipeline where mobilised sediments had partially buried the rock armour there was less than 5% coverage, made up of sea fans, sea whips, feather stars, hydroids and algae.

In sections where the pipeline was suspended over troughs in undulations in the seabed, it supported abundant sea fans and sea whips (>90% cover) along with algae, laminar sponges, bryozoans and feather stars. By contrast, the exposed rock-armour positioned where the pipeline passed into the trenched seabed harboured low biotic abundance, dominated by algae with a silt veneer.

Source: URS 2009c.

Figure 3-19: Sea fans, sea whips and sponges on the rock armour covering the existing Bayu–Undan Gas Pipeline

Dredge spoil disposal ground

In order to characterise benthic habitats at the offshore spoil disposal ground (12 km north-west of Lee Point), 100%-coverage sidescan sonar and echo-sounder surveys were conducted by EGS Earth Sciences and Surveying in February 2009. The surveys recorded a flat featureless seabed of silt–sand, at water depths of 15–20 m. This seabed environment is common throughout the Anson–Beagle Bioregion and would likely support sparse benthic communities such as burrowing infauna. The survey was also used to search for any shipwrecks that might have occurred within the spoil disposal ground: none were recorded (EGS 2009).

To further investigate the benthic habitats in the area, a drop-camera survey was completed in September 2009 by Tek Ventures Diving Services (TVDS). The survey covered 21 sites, one per square kilometre of the spoil disposal ground and the surrounding buffer area. Photographs taken during the survey recorded a generally featureless seabed of a sand and/or silt substrate. Very sparse epibenthic fauna was recorded at nine of the sites, typically consisting of occasional bryozoans, sponges and soft corals, with sparse bioturbation (figures 3-20 and 3-21). No seagrasses were recorded in the survey. These results are described further in Appendix 8.

The benthic habitats recorded correlate with mapping of coastal and offshore seabed sediments in the Anson–Beagle Bioregion previously undertaken by NRETAS. Seafloor sampling by Smit, Billyard and Ferns at sites in the vicinity of the offshore spoil disposal ground found the seabed to be primarily composed of carbonate sand. Sparse communities of benthic invertebrates were present, and included bryozoans (which are often associated with coarse-grained sediments), small crabs and shrimps, and worms. Similar sediments and invertebrate communities are widespread across the Anson–Beagle Bioregion (Smit, Billyard & Ferns 2000).

No seagrasses were found by Smit, Billyard and Ferns (2000) in the vicinity of the spoil disposal ground. They considered that extensive seagrass beds would not occur in waters deeper than 5 m, noting that turbid waters were not conducive to seagrass growth. Light levels at water depths of 15–20 m in the region are highly unlikely to be sufficient to support seagrass photosynthesis and growth. The nearest known seagrass meadow is located just off the coast from Casuarina Beach, some 10 km to the south-east (across current) of the spoil disposal ground (N. Smit, Marine Biodiversity Group, NRETAS, pers. comm. July 2009).

3.3.8 Protected species

There are a number of threatened marine species that may be present in the nearshore development area and that are protected under Northern Territory legislation, Commonwealth legislation or international agreements.

Commonwealth and Northern Territory legislation

As described for the offshore marine environment in Section 3.2.8 *Protected species*, the EPBC Act provides a legal framework to protect and manage nationally and internationally threatened plants and animals—defined in the EPBC Act as “matters of national environmental significance”. In addition to locally threatened species, the EPBC Act protects all cetaceans in Australian waters as well as a range of marine and migratory species that are listed under international treaties and conventions (as described below).

Similarly, the Biodiversity Conservation Unit of NRETAS is charged under Section 29 of the TPWC Act with administering the Northern Territory’s Threatened Species List and for assessing and classifying the conservation status of all wildlife species occurring in the Northern Territory.

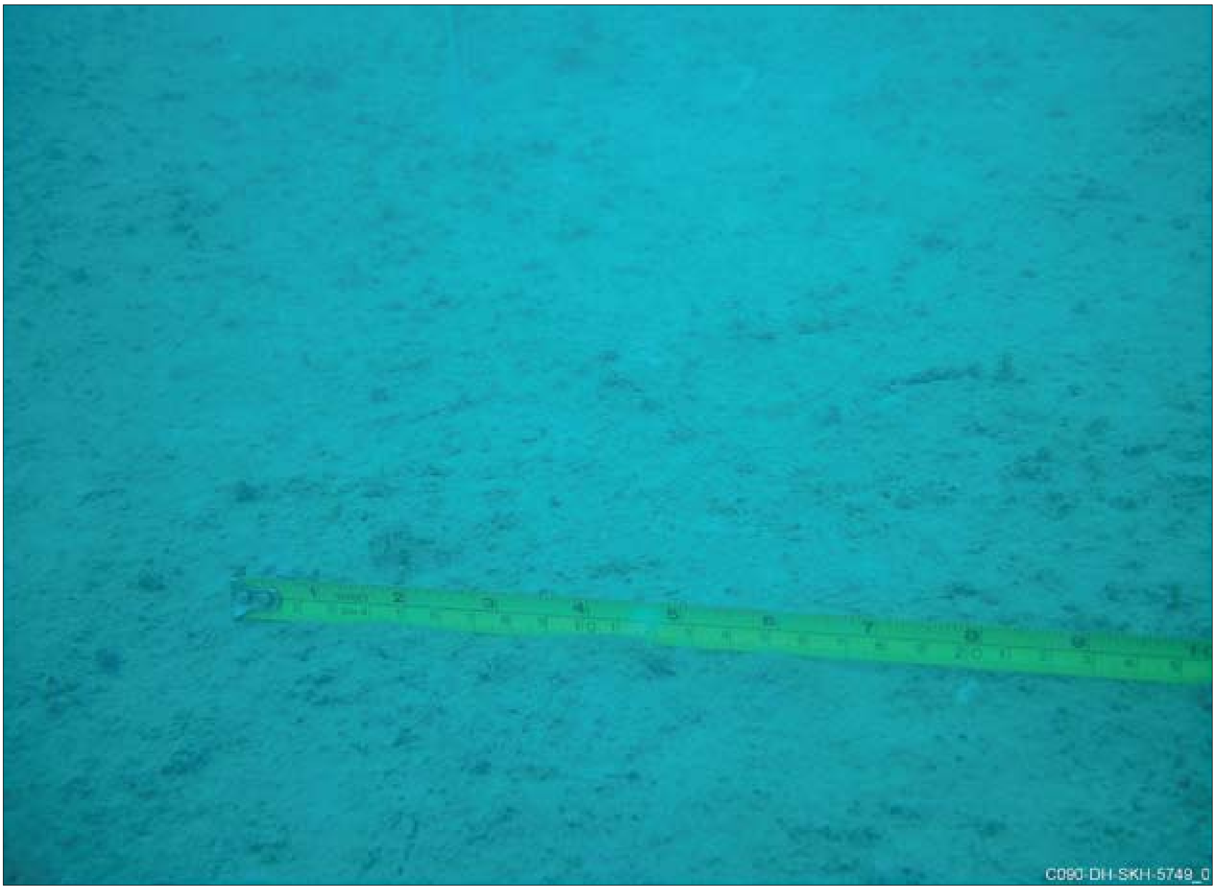


Figure 3-20: Sand and silt substrate recorded at the offshore spoil disposal ground

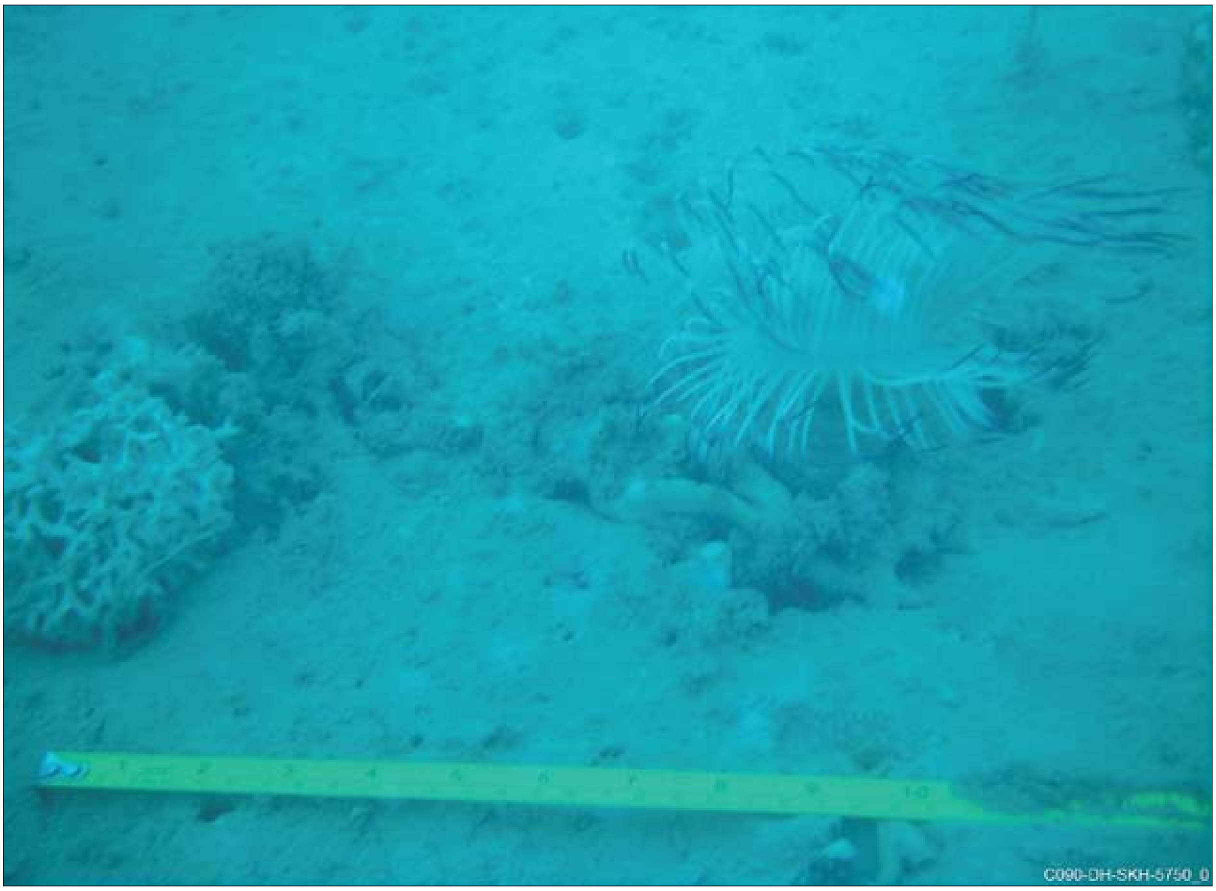


Figure 3-21: A bryozoan and an anemone on the sand and silt substrate at the offshore spoil disposal ground

Marine species categorised as “critically endangered”, “endangered” or “vulnerable” under the TPWC Act and EPBC Act and that may be present in or near the proposed nearshore development area are listed in Table 3-8. It is noted that other marine species that fall under less critical conservation categories (such as listed “cetacean” or “migratory” species, or “near threatened” species) also occur in the nearshore development area—key species from these categories are discussed further in this section.

International protection and conservation status

As noted in Section 3.2.8, marine animals that are considered to be under threat of extinction are listed on The IUCN Red List of Threatened Species. They may otherwise be protected by CITES, or by the Bonn Convention. Species that may inhabit the nearshore development area and are protected by such conventions, laws and similar are listed in Table 3-8.

Table 3-8: Protected marine species that may be present in or near the nearshore development area

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention§	CITES#
Cetaceans: whales						
Balaenoptera musculus	Blue whale	E	–	E	I	I
Megaptera novaeangliae	Humpback whale	V	–	V	I	I
Reptiles						
Caretta caretta	Loggerhead turtle	E	E	E	I, II	I
Chelonia mydas	Green turtle	V	–	E	I, II	I
Dermochelys coriacea	Leatherback turtle	E	V	CR	I, II	I
Eretmochelys imbricata	Hawksbill turtle	V	–	CR	I, II	I
Lepidochelys olivacea	Pacific ridley turtle**	E	–	E	I, II	I
Natator depressus	Flatback turtle	V	–	–	II	I
Cartilaginous fish: sharks						
Pristis microdon	Freshwater sawfish	V	V	CR	–	II
Pristis zijsron	Green sawfish	V	V	CR	–	I
Rhincodon typus	Whale shark	V	–	V	II	II
Ray-finned fishes						
Hippocampus kuda	Spotted seahorse	–	–	V	–	–
Hippocampus planifrons	Flat-faced seahorse	–	–	V	–	–
Hippocampus spinosissimus	Hedgehog seahorse	–	–	V	–	–

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
E = Endangered; V = Vulnerable.

‡ International—IUCN: The IUCN Red List of Threatened Species.
CR = Critically Endangered; E = Endangered; V = Vulnerable.

§ International—Bonn Convention: Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals.
I = Appendix I Endangered Migratory Species; II = Appendix II Migratory Species.

# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

** The Pacific ridley turtle is also known as the olive ridley turtle.

Cetaceans

While the blue whale (*Balaenoptera musculus*) is listed as a potential inhabitant according to the public threatened-species database (DEWHA 2009a; see Table 3-8), Darwin Harbour is not blue whale habitat. Likewise, humpback whales (*Megaptera novaeangliae*) are known to migrate to northern Australian waters during June to August, but the species rarely ventures as far north and east as Northern Territory waters.

The most commonly recorded cetacean species in Darwin Harbour are three coastal dolphins—the Australian snubfin (*Orcaella heinsohni*), the Indo-Pacific humpback (*Sousa chinensis*) and the Indo-Pacific bottlenose (*Tursiops aduncus*) (Palmer 2008). An oceanic dolphin, the false killer whale (*Pseudorca crassidens*), has also been recorded in Darwin Harbour (Palmer et al. 2009; Whiting 2003). The current conservation status of each of these species is shown in Table 3-9.

The snubfin dolphin (Figure 3-22) is a recently described species, having previously been considered to be a population of the Irrawaddy dolphin (*O. brevirostris*). Recent morphological and genetic studies on specimens of the genus *Orcaella* have shown that populations in north-eastern Australia are distinct at species level from the South-East Asian populations; this means that the snubfin dolphin is endemic to Australia and is Australia's only endemic cetacean (Beasley, Robertson & Arnold 2005).

The taxonomic revision was based on a range of features and included genetic sampling from South-East Asian and northern Queensland populations, as well as one sample from the Northern Territory. At present, it is believed that the distribution of the snubfin dolphin extends from Broome in Western Australia to Brisbane in Queensland (DEWHA 2009d). Preliminary genetic studies on mitochondrial DNA in snubfin dolphins from Western Australia, the Northern Territory and Queensland indicate that the overall population is genetically similar and does not contain subspecies. Further and more detailed genetic studies are under way to better characterise the extent of gene flow between local dolphin populations (Palmer 2010).

Photograph courtesy of Dr Guido J. Parra, Flinders University.

Figure 3-22: Australian snubfin dolphin (Orcaella heinsohni)

Aerial surveys conducted by Freeland and Bayliss in 1984–85 (prior to the taxonomic separation of the Irrawaddy dolphin and the Australian snubfin dolphin) identified large numbers of "Irrawaddy" dolphins in the waters of the Gulf of Carpentaria in the eastern Northern Territory. These dolphins were particularly associated with major shrimp breeding grounds at Blue Mud Bay and inhabited waters between 2.5 m and 18 m deep. By comparison, few "Irrawaddy" dolphins were recorded in the waters of the north-west coast of the Northern Territory (which included Darwin Harbour, the Tiwi Islands and the Cobourg Peninsula). Numbers recorded in that survey were too low to form an estimate of the total population in the area (Freeland & Bayliss 1989). There is currently no overall population estimate available for snubfin dolphins in Australia.

More recently, the Northern Territory Government has commenced a coastal dolphin research project in Darwin Harbour and in the broader Anson–Beagle Bioregion. Preliminary observations since 2008 have identified relatively high numbers of snubfin dolphins at

Table 3-9: Conservation status of dolphins found in Darwin Harbour

Species	Conservation status			
	EPBC Act 1999 (Cwlth)	IUCN Red List*	Bonn Convention†	TPWC Act (NT)
Australian snubfin dolphin *Orcaella heinsohni*	Cetacean‡; Migratory	Near threatened	Migratory	Least concern
Indo-Pacific humpback dolphin *Sousa chinensis*	Cetacean‡; Migratory	Near threatened	Migratory	Least concern
Indo-Pacific bottlenose dolphin *Tursiops aduncus*	Cetacean‡; Migratory	Data deficient	Migratory	Least concern
False killer whale *Pseudorca crassidens*	Cetacean‡	Data deficient	Not listed	Least concern

* IUCN 2009b.

† Bonn Convention 2009a.

‡ All cetaceans are protected in Australian waters under the EPBC Act.

Cobourg Peninsula and in the South and East Alligator rivers (Kakadu National Park). While snubfin dolphins have also been observed in Darwin Harbour and Shoal Bay, the numbers there have been noticeably lower than in these other parts of the Northern Territory coast. The Darwin Harbour and Shoal Bay study has so far surveyed 2347 km of systematic transects and recorded 33 snubfin dolphins in 10 schools (0.01 dolphin per kilometre). Snubfin dolphins have been recorded on the east and west sides of Darwin Harbour, near Lee Point and in Shoal Bay. Population estimates for snubfin dolphins in the Darwin Harbour – Shoal Bay area have not yet been developed, but research is continuing (Palmer 2010).

Indo-Pacific humpback dolphins are widespread and relatively common throughout Australian tropical waters from Shark Bay (Western Australia) north through the Northern Territory, Queensland and northern New South Wales (Mustoe 2008). The species is also believed to extend through the Indo-Pacific region as far as Borneo, the Indian subcontinent, the Gulf of Thailand, the South China Sea and the coast of China to the Changjiang River (Ross 2006). Relatively little is known regarding the ecology and population status of this species throughout most of its range. The exception to this is off the coast of South Africa and in Hong Kong waters, where Indo-Pacific humpback dolphins have been relatively well studied (Parra, Schick & Corkeron 2006).

However, recent genetic studies on Indo-Pacific humpback dolphins indicate that, as with the Australian snubfin dolphin, the Australian Indo-Pacific humpback populations may also be a separate species found only in Australian waters. At this stage, very few DNA samples have been taken in the Northern Territory or north-west Western Australia (Palmer 2008).

Preliminary observations from the Northern Territory coastal dolphin studies indicate that relatively high numbers of Indo-Pacific humpback dolphins occur in Darwin Harbour, as well as at Cobourg Peninsula and the Alligator rivers. The Darwin Harbour surveys have so far recorded 284 humpback dolphins in 88 schools (0.12 dolphin per kilometre) (though a proportion of these will be individuals that are being re-recorded) throughout the areas surveyed in Darwin Harbour and Shoal Bay. Population estimates have not yet been developed (Palmer 2010).

Observations from the Northern Territory coastal dolphins research project indicate that shallow, intertidal areas in Darwin Harbour and Shoal Bay are regularly utilised by Australian snubfin and Indo-Pacific humpback dolphins (Palmer 2010). This correlates with knowledge of these species from elsewhere around northern Australia, where habitat preferences for both species are described as coastal and estuarine waters less than 20 m deep, close to river mouths and creeks, with foraging undertaken in mangrove communities, seagrass beds and sandy-bottom environments through to open coastal waters with rock and/or coral reefs (DEWHA 2010). Darwin Harbour contains only limited areas of seagrass, but river-mouth, mangrove, sandy-bottom, rocky reef and coral habitats do occur throughout the Harbour and Shoal Bay.

Other studies on habitat preferences in Cleveland Bay near the Port of Townsville in northern Queensland indicated that dolphin species utilised areas close to river mouths and modified habitat such as dredged channels and breakwaters. Shallow areas with seagrass ranked high in the habitat preferences of snubfin dolphins, whereas humpback dolphins favoured dredged channels. Both species appeared to be opportunistic generalist feeders, eating a wide variety of fish both on the seabed and within the water column (Parra 2006).

Four snubfin dolphin calves have been recorded in Darwin Harbour during the Northern Territory coastal dolphin study—three near Mandorah and one near East Point—while 34 humpback dolphin calves have been recorded throughout the Darwin Harbour and Shoal Bay survey areas. There appears to be a wet-season peak in observations of calves of both species (Palmer 2010). Little is known of the reproductive biology or population structure of either species (Parra, Schick & Corkeron 2006; Ross 2006).

From the current understanding of the ecology of these two species, it is reasonable to conclude that potential habitat for snubfin and Indo-Pacific humpback dolphins occurs throughout Darwin Harbour, in both soft- and hard-substrate areas near mangroves and rocky reefs.

Research on the snubfin dolphin and the Indo-Pacific humpback dolphin in Cleveland Bay indicated that both species showed site fidelity, returning to the bay as part of a larger home range, with movement patterns following a regular model of annual emigration and re-immigration. Freshwater input from a river system was a feature of the area to which the dolphins regularly returned. Cleveland Bay was not found to be a permanent residence area for the species and the dolphins were expected to be utilising adjacent coastal areas (rather than offshore waters) when outside the bay. Home ranges and territories for the species appeared to be large, as many of the identified individuals spent less than 30 days within the 310-km^2 Cleveland Bay study area (Parra, Corkeron & Marsh 2006).

A similar study on site fidelity has not yet been undertaken for the snubfin and Indo-Pacific humpback dolphins of Darwin Harbour and Shoal Bay, although research is currently under way. Even so, any dolphins that regularly utilise Darwin Harbour and Shoal Bay may do so as part of a wider home range, wherever freshwater input from rivers occurs.

Van Parijs, Parra and Corkeron (2000) investigated the vocalisations of snubfin dolphins and found that they produce broadband clicks, at least three types of pulsed sounds and two low-frequency whistles. The clicks and pulsed sounds, predominantly used during foraging, were of very high frequency at >22 kHz. The whistles produced by the dolphins, however, were much lower in frequency, at 1–8 kHz, were simple in form compared with other delphinid species, and were used during both socialising and foraging.

The Indo-Pacific bottlenose dolphin occurs from South Africa to the Red Sea and eastwards to the Arabian Gulf, India, China and Japan, southwards to Indonesia and New Guinea, and to New Caledonia. The species occurs around the whole Australian coast and frequents a large number of bays and inshore waters in considerable numbers, including parts of the northern coast of Tasmania. It is a coastal species and generally occurs in waters less than 20 m deep. Studies on South African populations of Indo-Pacific bottlenose dolphins suggested that the species rarely migrates and that females stay close to their birthplace throughout their lives (Ross 2006). The ecology of the population in Northern Territory waters has not been researched in detail.

Pods of false killer whales are known to visit the Harbour but little research has been conducted into their utilisation of the area (Palmer 2010; Whiting 2003). Other cetaceans that have been recorded in the Harbour include the sperm whale (*Physeter macrocephalus*), the pygmy sperm whale (*Kogia simus*) and the humpback whale (*Megaptera novaeangliae*). Records of these species are rare, however, and represent sightings of individual vagrants.

Dugongs

Dugongs are known to occur in Darwin Harbour waters, although in relatively low numbers, probably because of the paucity of seagrass habitat (Whiting 2008). As described in Section 3.2.8, dugongs have been recorded in higher densities at Gunn Point and the Vernon Islands, approximately 30–50 km north-east of the mouth of the Harbour. Dugongs have also been observed in relatively high numbers at Bare Sand Island and Dundee Beach in Fog Bay, 60 km south-west of Darwin Harbour (Whiting 1997; S. Whiting, marine biologist, NRETAS, pers. comm. February 2010). The species is known to travel long distances (Whiting 2003, 2008).

In Darwin Harbour, dugongs were observed foraging on the rocky reef flats between Channel Island and the western end of Middle Arm Peninsula in a three-year study conducted by Charles Darwin University and Biomarine International. As no seagrass occurs on the reef flat in this area, the dugongs were likely to have been feeding on macroalgae. Whiting (2008) suggests that this habit of foraging on the algae, sponge and coral communities of macrotidal reefs distinguishes dugongs in the Anson–Beagle Bioregion from conspecifics elsewhere. Dugongs had been observed foraging on algae on similar reefs in Fog Bay (Whiting 2002).

In general, it is considered that dugongs could occur anywhere in the Harbour that could support seagrasses or algae, which corresponds with hard-substrate areas in waters less than 10 m in depth and areas of rocky reef such as Weed Reef and Channel Island (Figure 3-23).

Waterbirds and seabirds

The protected waterbird and seabird species that may inhabit or frequent the nearshore and onshore development areas are described in Section 3.4.12 *Protected species*.

Turtles

As described in Section 3.2.8, six species of marine turtles are known to occur in Northern Territory waters (see Table 3-8). Of these, the green, hawksbill and flatback turtles utilise Darwin Harbour regularly, and the Pacific ridley and loggerhead turtles are suspected to be infrequent users (Whiting 2003). The leatherback turtle is considered to be an oceanic species and is unlikely to occur in Darwin Harbour (Whiting 2001).

The shoreline throughout Darwin Harbour, and particularly in Middle Arm and East Arm, consists largely of mangrove forests and mudflats and does not provide suitable nesting habitat for any species of turtle that may frequent the area (Dr M. Guinea, marine biologist, Charles Darwin University, pers. comm. September 2008). Turtles visiting the Harbour are more likely to be foraging for food.

Green turtles are predominantly herbivorous and feed on seagrasses and algae. Immature and adult green turtles have been observed in a variety of habitats throughout Darwin Harbour feeding on sparse seagrass, algae and mangrove seedlings and fruits (Metcalfe 2007; Whiting 2003). Published records include observations of relatively high numbers of green turtles foraging on the intertidal reef flats between Channel Island and Middle Arm Peninsula, particularly in the dry season when algae are more abundant (Whiting 2001). On the assumption that green turtles could utilise any area where seagrass,

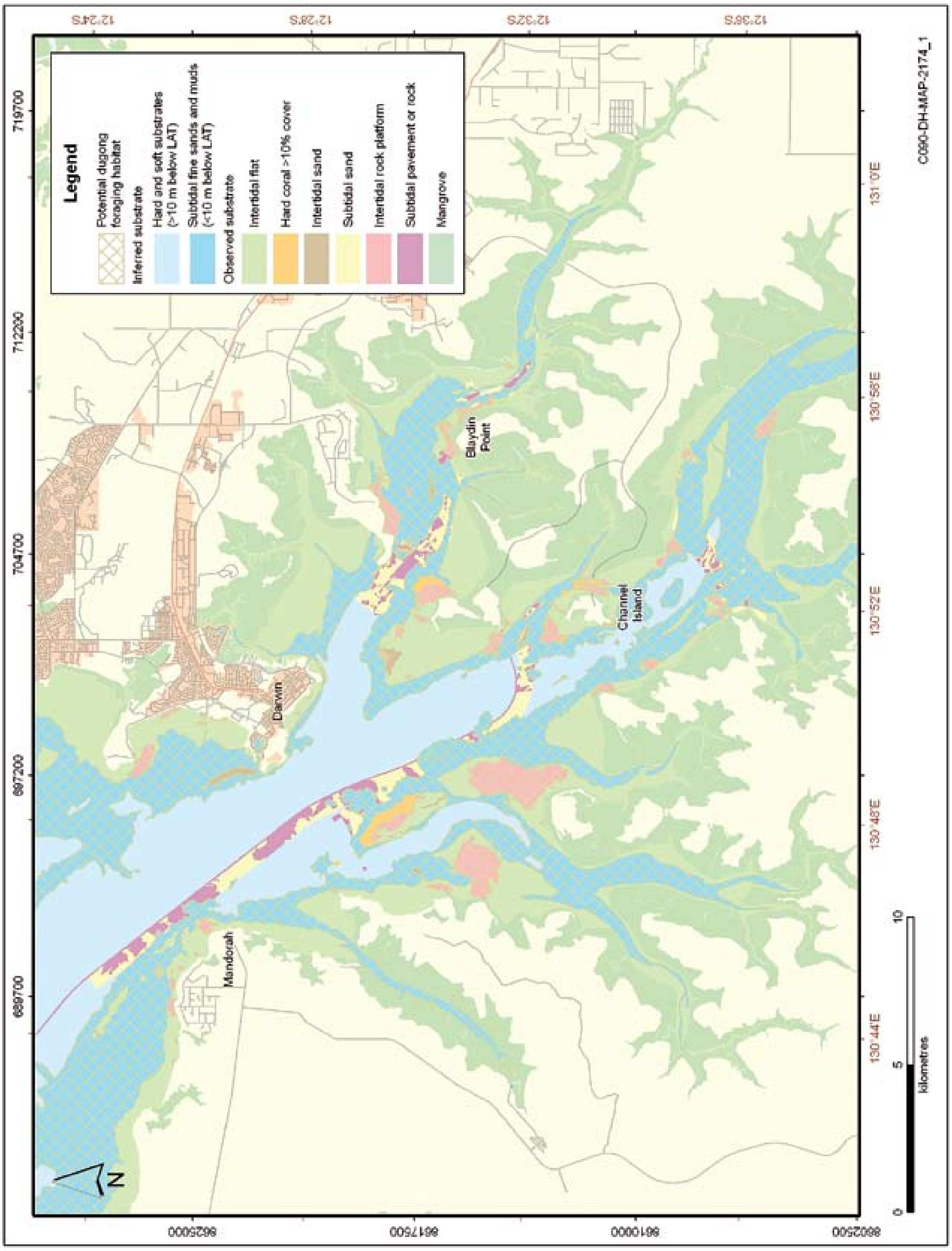


Figure 3-23: Potential dugong habitat in Darwin Harbour

fringing mangrove or macroalgae habitats are available, their potential habitat in Darwin Harbour is presented in Figure 3-24.

Hawksbill turtles are omnivores, feeding particularly on sponges but also on seagrasses, algae, soft corals and shellfish. In Darwin Harbour, immature and adult-sized hawksbill turtles have been reported using rocky reef habitat at Channel Island, but they may also utilise other habitats (Whiting 2001). Hawksbill turtles occur in Darwin Harbour at lower abundances than green turtles, with around four times as many green turtles recorded at the Channel Island foraging area as hawksbill turtles (Whiting 2001). As their preferred foods occur on hard substrates throughout intertidal and subtidal areas of the Harbour, hawksbill turtles could utilise any of the areas indicated in Figure 3-25.

The flatback turtle is carnivorous, feeding mostly on soft-bodied prey such as sea cucumbers, soft corals and jellyfish, which are found mainly in subtidal, soft-bottomed habitats. While flatback turtles are the most commonly encountered nesting species in the Anson–Beagle Bioregion (Chatto & Baker 2008), only limited, low-density nesting has been observed in Darwin Harbour—at Cox Peninsula near Mandorah and at Casuarina Beach. Potential habitat for any flatback turtles foraging in Darwin Harbour is shown in Figure 3-26.

Seasnakes

Although they are only infrequently seen, a diverse range of marine and mangrove-dwelling snakes occur in Darwin Harbour (URS 2002).

The diet of most seasnakes in the Harbour consists of fish, fish eggs and crustaceans that they capture either in the Harbour waters or on the exposed mudbanks. The bockadam (*Cerberus rynchops*) and the white-bellied mangrove snake (*Fordonia leucobalia*) are more commonly encountered than Richardson's mangrove snake (*Myron richardsonii*). The little filesnake (*Acrochordus granulatus*) is the only marine representative of the non-venomous acrochordids that specialise in capturing fish (Whiting 2003). The black-ringed seasnake is the most commonly encountered as it feeds on the mudflats during daylight hours (Guinea, McGrath & Love 1993). Other species such as the yellow-bellied seasnake (*Pelamis platurus*) are rarely encountered because of their pelagic habits, but enter the waters adjacent to Darwin Harbour (Guinea 1992).

The Port Darwin seasnake (*Hydrelaps darwiniensis*) comes ashore on the mudflats during daylight hours to feed on gobies that have retreated to their burrows during low tide (Guinea, McGrath & Love 1993).

Saltwater crocodile

While it is not a threatened species under Northern Territory or Commonwealth legislation, the saltwater crocodile (*Crocodylus porosus*) is listed in CITES under Appendix II. It therefore also appears as a listed marine species under the EPBC Act. This protection is applied to regulate commercial hunting, particularly for the trade in crocodile skins, which historically has resulted in population declines. Today's export-oriented crocodile industry is regulated and wild populations of the species are not considered threatened (PWSNT 2005).

The saltwater crocodile occurs in Darwin Harbour. In the interests of public safety, its abundance here is controlled by a trapping and removal program conducted by the PWSNT. Nesting sites for the saltwater crocodile are limited inside the Harbour, and the area is not considered critical habitat for crocodile survival in the Northern Territory (Whiting 2003).

Ray-finned fish

As is the case for the offshore development area (see Section 3.2.8), there are three seahorse species from the IUCN's Red List that could potentially occur in the Harbour (see Table 3-8); however, the distribution ranges of these are not well known. The flat-faced seahorse has only been recorded in Western Australian waters, the hedgehog seahorse is unrecorded in Australian waters, and the spotted seahorse is found across the Indo-Pacific region (Allen & Swainston 1988; Seahorse Australia 2008). None of these species are listed as threatened under Northern Territory legislation and very little is known of their presence or distribution in Darwin Harbour.

Sharks and other cartilaginous fish

The public threatened-species database (DEWHA 2009a) suggests that the freshwater sawfish, green sawfish and whale shark could occur in the waters of Darwin Harbour, although none have yet been formally recorded in the Harbour.

The freshwater sawfish is a medium-sized sawfish that prefers muddy bottoms of freshwater areas and upper reaches of estuaries. In the Northern Territory, it occurs in the upper reaches of rivers across the Top End from the Keep, Victoria and Daly rivers in the west to the McArthur and Robinson rivers in the east. The species has been reported to spend the first three to four years in fresh water, then to migrate into marine waters after the wet season, and then to return to the estuaries to breed during the following wet season (Larson, Stirrat & Woinarski 2006). It is not known to occur in Darwin Harbour.

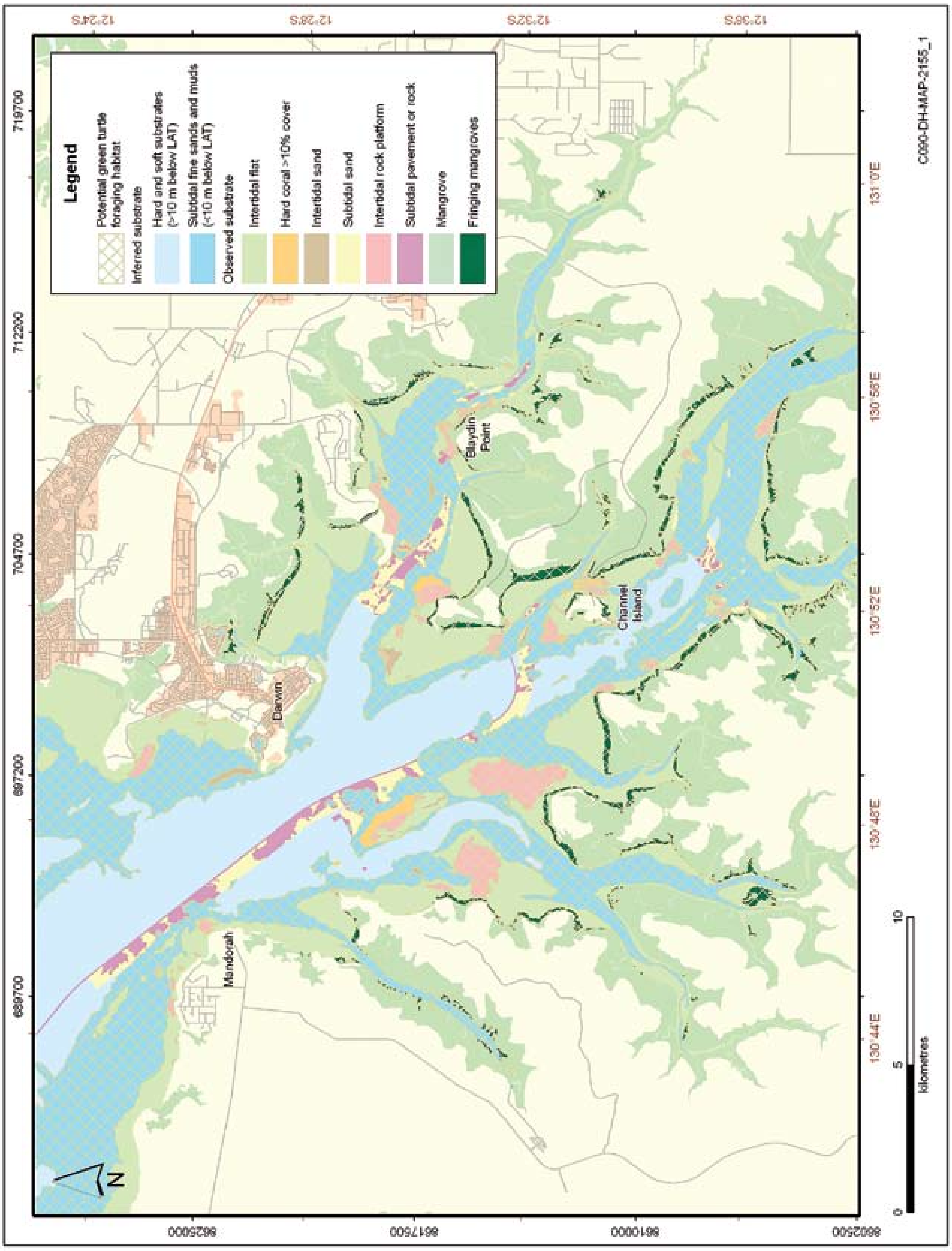


Figure 3-24: Potential green turtle foraging habitat in Darwin Harbour

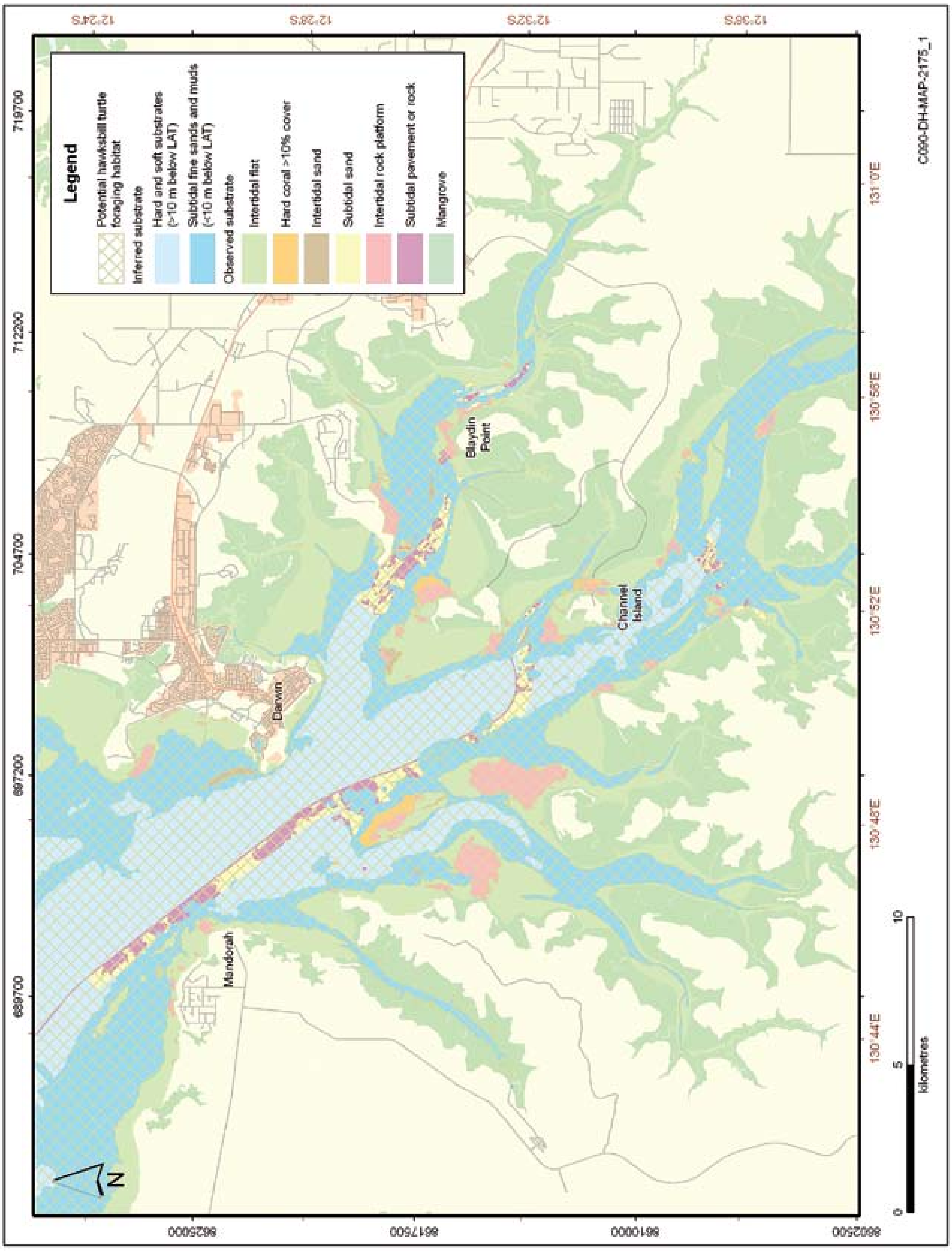


Figure 3-25: Potential hawksbill turtle foraging habitat in Darwin Harbour

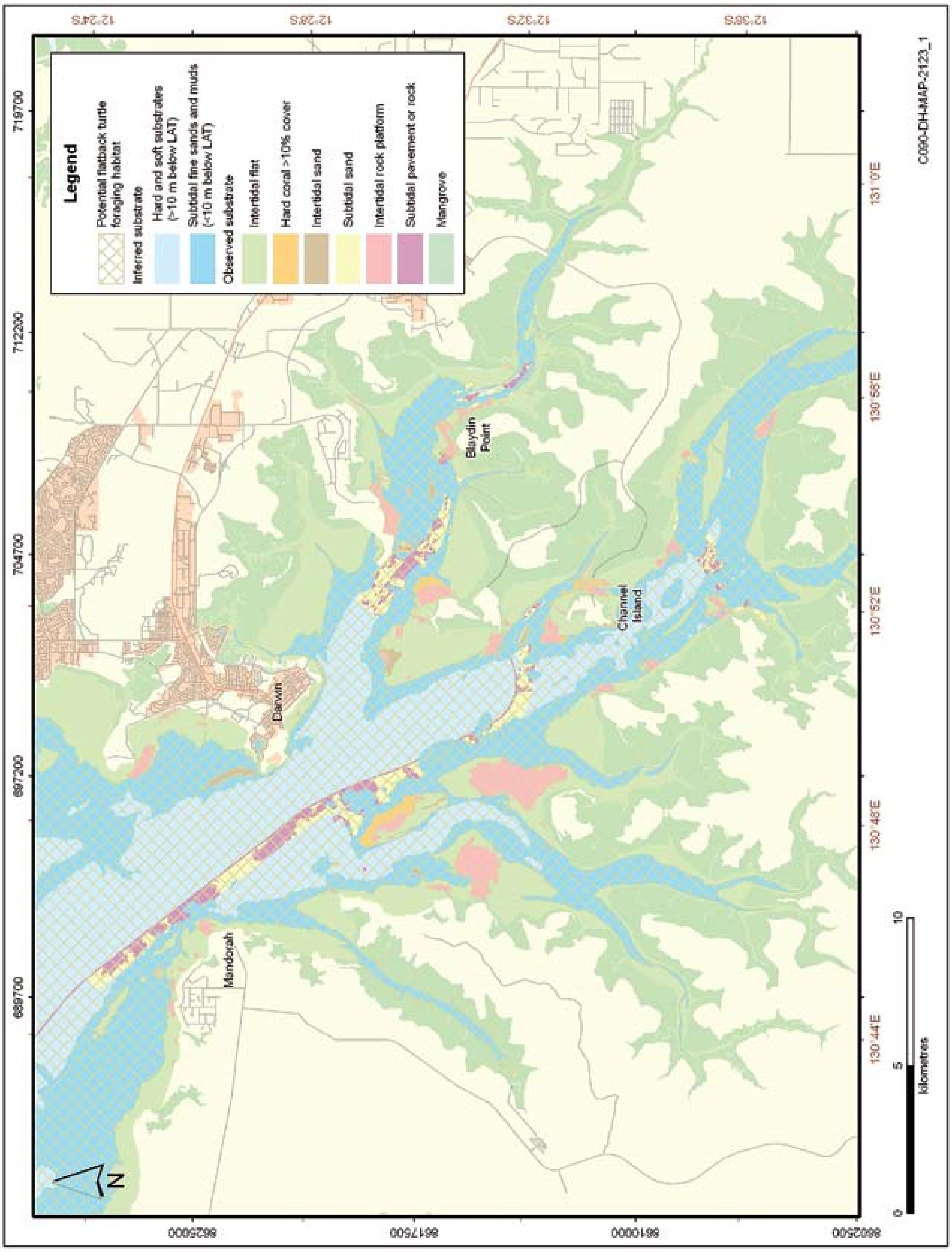


Figure 3-26: Potential flatback turtle foraging habitat in Darwin Harbour

The green sawfish lives on muddy or sandy-mud soft-bottom habitats in inshore areas. It also enters estuaries, where it has been recorded in very shallow water. The green sawfish is widely distributed in the northern Indian Ocean and around Indonesia and Australia. It is the most commonly encountered sawfish species in Australian waters (Last & Stevens 1994) and is more commonly found in Australian tropical waters. In the Northern Territory, specimens have been collected only in Buffalo Creek just outside Darwin Harbour (Stirrat, Larson & Woinarski 2006).

Whale sharks have a broad distribution in tropical and warm temperate seas. In Australian waters, they are known to aggregate at Ningaloo Reef (Western Australia) and in the Coral Sea. The whale shark is a highly migratory fish and only visits Australian waters seasonally, in response to localised seasonal "pulses" of food productivity (DEH 2005b). Its migration path is not known to include Darwin Harbour and only anecdotal records are known from around the Northern Territory coastline (Woinarski et al. 2007).

3.3.9 Marine pests

Marine pests are introduced marine species that have been translocated from their natural environment to an area where they can threaten biodiversity, fisheries and other commercial or recreational values. Native species are threatened by marine pests through competition for food and habitat, or through modification of local ecosystems. Maritime structures and vessels can also be damaged by marine pests that can clog cooling-water intakes and foul the hulls and seawater systems of boats, reducing speed and fuel efficiency (DoR 2009a). Broadly speaking, marine pest risks are highest in shallow water close to land.

The National Introduced Marine Pests Coordination Group has identified 55 marine species that are known to be invasive in Australia, are invasive elsewhere, or are considered to be potentially invasive. The list includes various starfish, bivalves and algae that can be found attached to vessel hulls, as well as dinoflagellates and diatoms that can be transported in vessel ballast water. National monitoring programs at ports throughout Australia target these species, although acknowledging that other species might also be detected and identified as marine pests. None of these 55 target species are known to occur in Darwin Harbour (Wells 2008) and the region is considered to be free of marine pests.

In 1999 a population of the highly invasive black-striped mussel (*Mytilopsis sallei*) was detected in marinas in Darwin Harbour. A multimillion-dollar eradication program was put in place and was successful in eradicating the mussels. This exercise is the only instance of the successful eradication of an alien marine species from Australian waters and the program attracted national publicity. Since then, the Department of Resources (DoR)[6] has applied a rigorous biofouling inspection and control regime to all vessels intending to enter Darwin's marinas.

3.4 Terrestrial environment

As described in Section 3.1.1, the onshore development area includes the terrestrial environment above the low-water mark at Blaydin Point and parts of Middle Arm Peninsula (see Figure 3-3). An access road and pipeline corridor also extend the onshore development area across Middle Arm Peninsula to the pipeline shore crossing at the water's edge south of Wickham Point. An aerial view of Blaydin Point is provided in Figure 3-27.

3.4.1 Bioregional setting

Terrestrial bioregions represent broad landscape patterns resulting from a range of factors, including geology, climate and biota. The Project's onshore development area is located in the Darwin Coastal Bioregion, which is defined by the Australian Natural Resources Atlas (ANRA) as the coastal area from near the mouth of the Victoria River to just west of the Cobourg Peninsula (see Figure 3-28). This bioregion incorporates the floodplains associated with the lower reaches of many large river systems, including the Moyle, Daly, Mary, Finniss, Adelaide, South Alligator and East Alligator rivers (DEWHA 2009e).

The Australian Natural Resources Atlas considers the bioregion to be in reasonably good condition, although degradation has occurred in some areas because of clearing for urban development and horticulture, weed infestations, saltwater intrusion into the floodplains

6 The Northern Territory's Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR) became the Department of Resources (DoR) in December 2009.

Figure 3-27: Blaydin Point, looking north-west towards Darwin

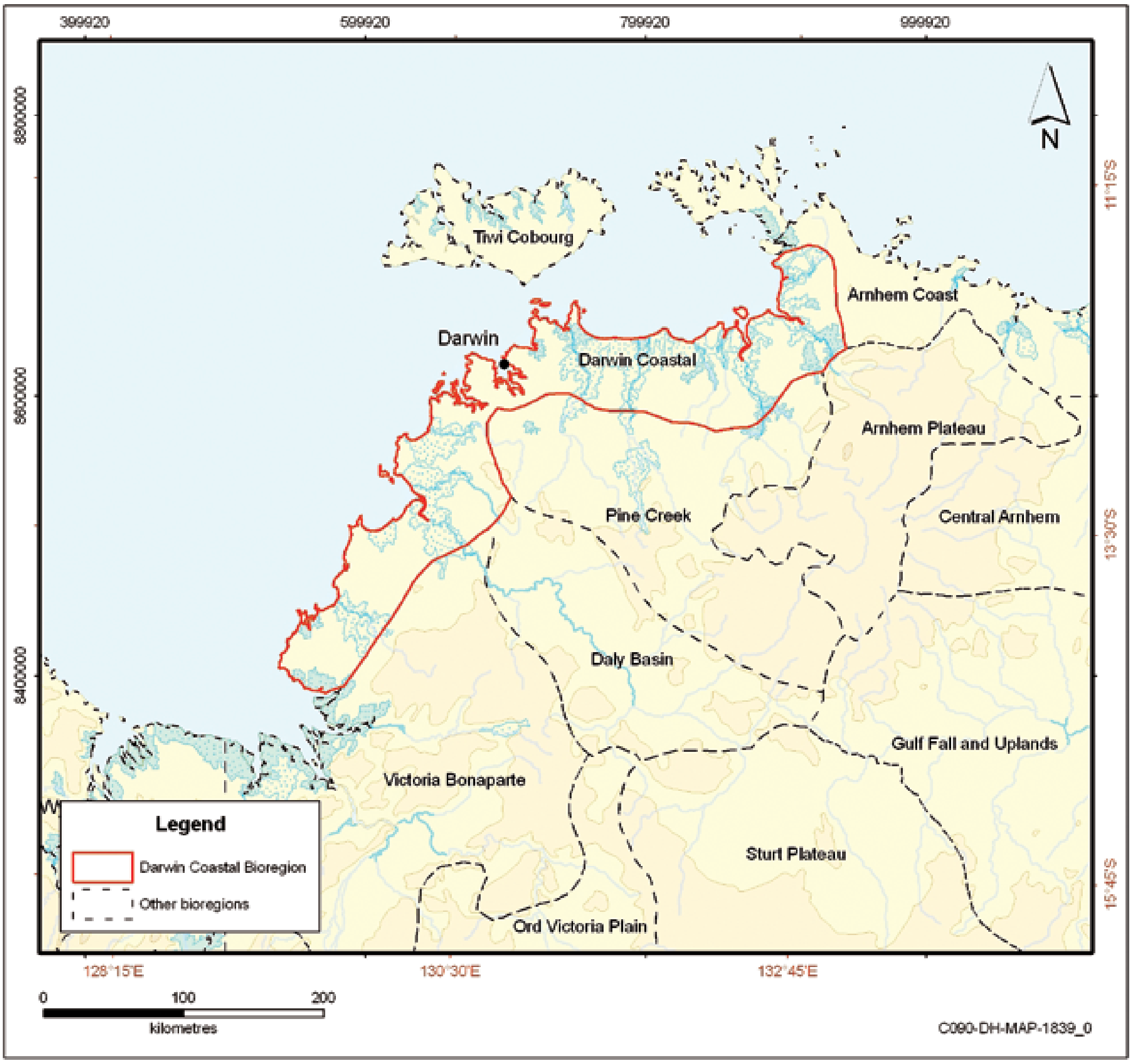


Figure 3-28: The Darwin Coastal Bioregion

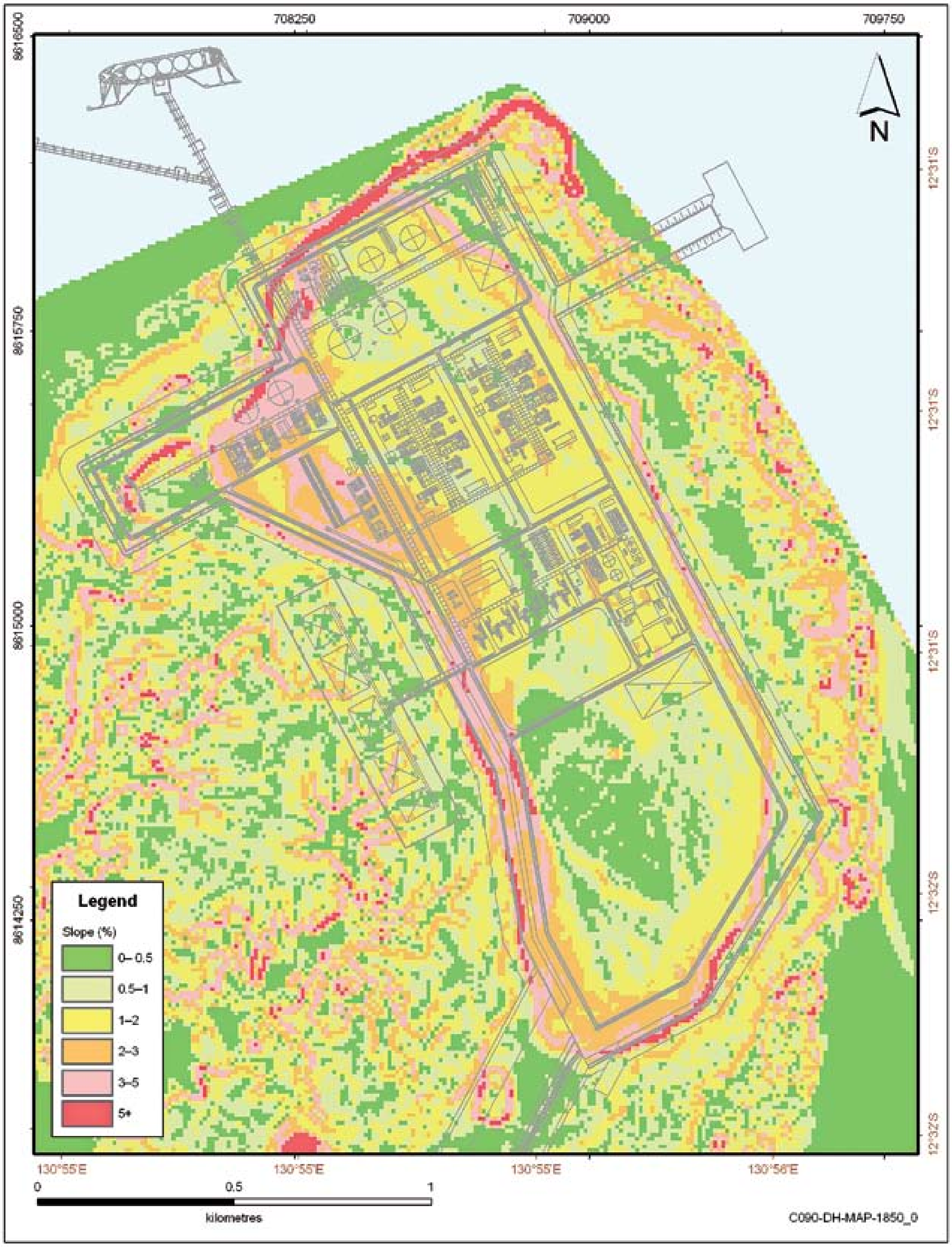
of several major river systems, changed fire regimes and feral animals. Almost 30% of the bioregion is contained in reserves, particularly to the north-east of Darwin (DEWHA 2009e).

3.4.2 Topography and geomorphology

The development of land surfaces in the north of the Northern Territory has traditionally been attributed to successive episodes of uplift, erosion and weathering (Hays 1967). The lower and younger two of the four land surfaces attributed to such development, the Wave Hill and Koolpinyah surfaces, dominate the landscape in the Darwin region (Hays 1967). However, investigations of the relationship between the Cretaceous stratigraphy and the nature of deep weathering in the Darwin region show that these surfaces are structurally controlled and detrital laterite profiles are considered to have formed in situ and are not markers for regional peneplain surfaces (Nott 1994).

Coastal morphology near Darwin is controlled mainly by the gentle warping of a lateritic profile. The lateritic cuirasse (duricrust) forms extensive shore platforms in synclines, but on the anticlines the pallid zone of the weathering profile is eroded by waves, causing the undercut cuirasse to collapse. The dominant modern process on the shore platforms is solutional attack on the laterite, resulting in large depressions (Nott 1994). Many of the platforms are covered by relict layers of cemented laterite cobbles transported by waves of high energy. Carbon-14 dating on carbonate cement between the cobbles shows that one sheet was deposited at about 3700 BP (before present) and the other sheet at about 1700 BP. Waves generated during devastating tropical cyclones last century had little effect on the cobble sheets, and they were probably transported onshore by tsunamis originating in the Indonesian archipelago prior to last century.

Blaydin Point is a low-lying peninsula oriented north–south, which juts out into East Arm. At its highest, the peninsula rises to approximately +10 m Australian Height Datum (AHD). Blaydin Point is separated from the mainland by a mudflat, across which a low causeway has been constructed by INPEX to provide access to Blaydin Point during spring-tide periods. This mudflat is subaerially exposed, except during spring tides. The topography of the onshore development area, presented as "percentage slope", is shown in Figure 3-29.



Source: URS 2009d.

Figure 3-29: Slopes of the land surface at Blaydin Point

Previous changes to the natural landform in the onshore development area include borrow pits on Middle Arm Peninsula. These cover around 25 ha, with maximum depths of about 5 m.

3.4.3 Regional geology

The Darwin region forms part of the Australian Precambrian Shield, which has been comparatively stable since middle Proterozoic times (Stuart-Smith et al. 1980). Metasediments of the Pine Creek geosyncline that overlie the Archaean basement were successively folded and uplifted during the early to middle Proterozoic. Flat-bedded Mesozoic and Cenozoic strata were deposited following erosion of the Proterozoic rocks.

Proterozoic strata in the Darwin region vary according to metamorphic grade. Near Cox Peninsula to the west the unconformable Cretaceous strata overlie upper greenschist to amphibolite facies, quartzofeldspathic and mica schists, gneiss and minor quartzite. To the east, near Gunn Point, lower greenschist facies metasediments occur. The Proterozoic strata underwent one major deformation approximately 1800 million years ago, resulting in tight folds with limbs dipping steeply at more than 50° (Pietsch 1986).

Regional geological mapping for Blaydin Point and its surrounds has been provided by the Northern Territory Geological Survey as part of the Bynoe map sheet compilation (Pietsch 1986) (see Figure 3-31). This information was compiled using aerial photography, traversing, outcrop mapping, stratigraphic drilling, and airborne magnetic and radiometric surveys. In addition, preliminary geotechnical investigations for the onshore development area were undertaken by Arup Pty Ltd in 2008. These involved drilling deep boreholes, excavating test pits and conducting cone penetrometer tests at key locations across Blaydin Point and the onshore pipeline route. The results of these site investigations were generally consistent with the broad-scale geological mapping provided by the government geological survey (Arup Pty Ltd 2008).

The onshore development area is underlain by Early Proterozoic and highly folded rocks of the Finnis River Group's Burrell Creek Formation (see Pfb in Figure 3-31). Some younger Lower Cretaceous rocks of the Darwin Formation (Kld) are exposed at the shoreline of Blaydin Point (Figure 3-30). The Burrell Creek Formation and the Darwin Formation are separated by a major unconformity, or buried erosion

Figure 3-30: Gravel base of the Cretaceous Darwin Formation overlying Proterozoic rocks at Blaydin Point

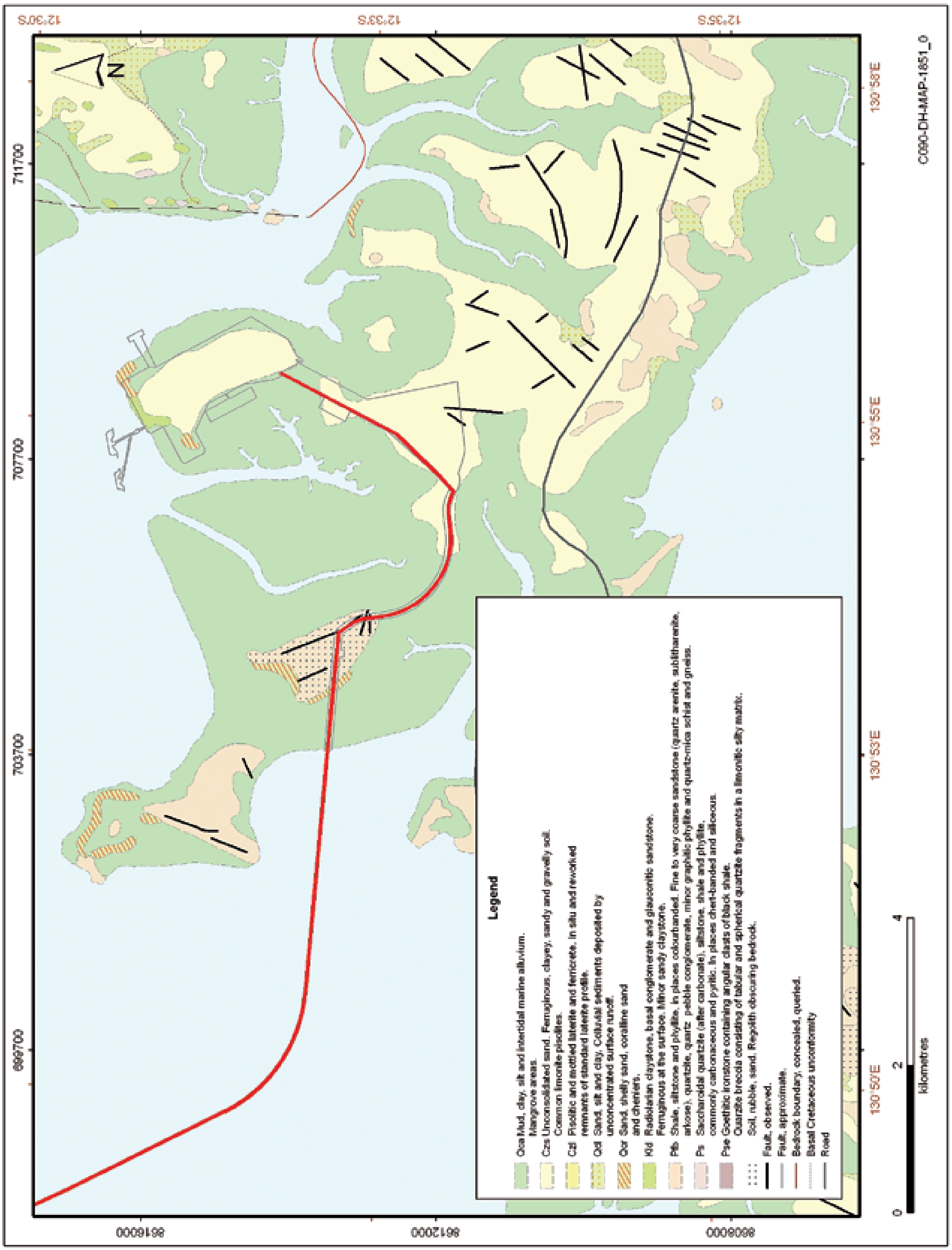
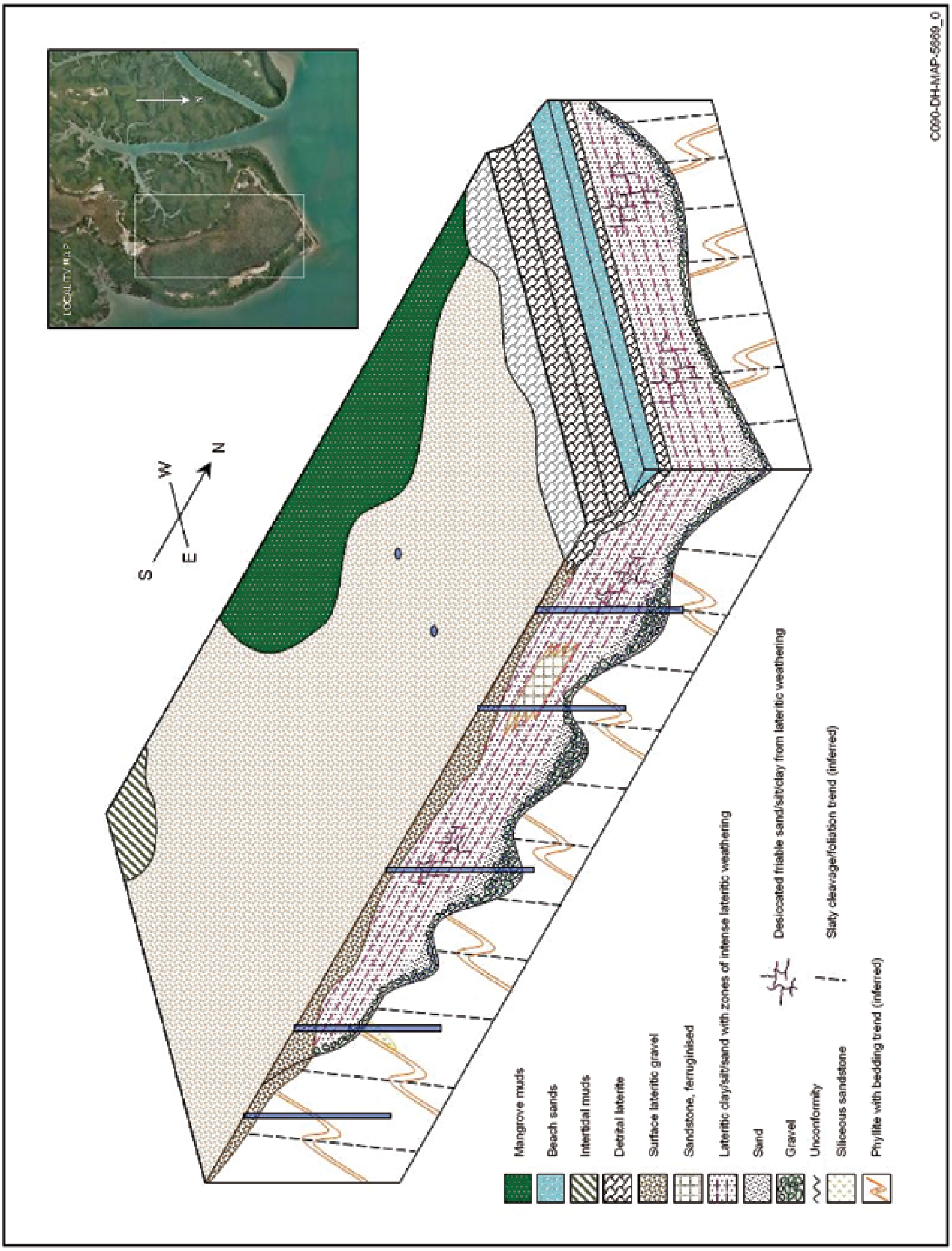


Figure 3-31: Geology of Blaydin Point and its surrounds



Source: Arup 2008.

Figure 3-32: Geological model of Blaydin Point, based on geotechnical investigations

surface, indicating that sediment deposition was not continuous (Arup Pty Ltd 2008).

Recent Quaternary marine alluvium (Qca) overlaps these older rocks. These materials have been subject to weathering and lateritisation for an extended period, possibly since late Cretaceous times (Arup 2008).

At Blaydin Point, the Burrell Creek Formation is dominated by finer-grained lutitic rocks, predominantly claystone and siltstone, which are understood to be steeply dipping and tightly folded. The ground investigation indicated that the Burrell Creek Formation has undergone low-grade regional metamorphism (prehnite–pumpellyite to lower greenschist facies) during the Top End Orogeny, and this metamorphism has altered the parent rocks to phyllites. Slates and possibly mica schist and gneiss are also believed to be present in the Burrell Creek Formation although these were not encountered during the ground investigation (Arup 2008).

Based on the site investigation, Arup (2008) developed a geological model representing the likely geological processes and conditions encountered at Blaydin Point. A three-dimensional graphical representation of the geological model for Blaydin Point is presented in Figure 3-32.

3.4.4 Soils

Soil morphology

Land unit surveys of the Blackmore and Elizabeth river catchments (Fogarty, Lynch & Wood 1984) have described soil morphology at 25 locations near the onshore development area in undulating (1–3% slope) to gently undulating (3–10%) terrain. Underlying rocks outcrop on crests and moderately deep to deep soils occur on deep weathered Cretaceous sediments in this undulating terrain. Estuarine mangrove, tidal flat and dune facies deposited during the Quaternary period fringe the Blaydin Point area.

The dominant soils covering over half the area on the undulating terrain were described as shallow (<0.25 m) to moderately deep (0.25–0.5 m), very gravelly massive earths. Soils in drainage lines and estuarine frontage are very poorly drained (hydrosols) and subject to regular or seasonal inundation and waterlogging. A very high risk of occurrence of ASSs was identified in these areas (Fogarty, Lynch & Wood 1984).

The Tertiary sediments and underlying rocks of the Lower Proterozoic metasedimentary formations (steeply dipping phyllites and schists) are weathered to a depth of approximately 40 m. The residual soils are typically lateritic with ferricrete layers often close to the surface or outcropping. Background levels of heavy metals tend to be elevated on similar land surfaces in this terrain.

Soil families in the onshore development area

In order to categorise the soils and landscape in the onshore development area, a soil-testing program was undertaken by URS in May 2008. The results of this survey are described below, while the full technical report (URS 2009d) is provided in Appendix 17 to this Draft EIS.

The Australian Soil Classification uses soil "orders" to describe soil types at a high level (Isbell 1996). The four soil orders present at the onshore development area are as follows:

- kandosols: massive soils with many fine pores, characterised by gradually increasing clay content and colour intensity with depth
- hydrosols: soils that are saturated for at least 2–3 months in most years and generally experience reducing conditions during the period of saturation
- organosols: deep soils that occur above the range of tidal inundation and where organic materials dominate in the surface 0.4 m
- podosol–tenosol complex: podosols have B horizons (subsurface soil layers) dominated by the accumulation of compounds of organic matter, aluminium and/or iron. These can occur in complex with tenosols, which are sand-dune soils with only weak pedological organisation apart from organic darkening in the A horizon (the surface soil layer).

Within these soil orders, a total of seven soil "families" was identified at Blaydin Point, defined by differences in soil colour, texture, depth and gravel content. These include three kandosols, one organosol, two hydrosols and one podosol–tenosol complex, as described below.

Kandosols

The Blaydin soil family occurs on flat crests and plateau surfaces in the onshore development area. This soil type is characterised by a well-structured A horizon that is very thick and melanic (high in organic matter, >5%) and is described as red, fine sandy clay loam. These soils are deep and support tall monsoon vine forest vegetation. The surface is easily disturbed and prone to dust generation and erosion once the vegetative cover is removed. The soil fertility level is high because of the enhanced organic carbon content.

The Hotham soil family occurs on crests and slopes in the onshore development area. The A horizon is brown in colour and described as massive, fine sandy loam with medium gravel (6–20 mm). These soils are deep and support tall, open eucalypt woodland vegetation.

The Koolpinyah soil family occurs on slopes in the onshore development area. These soils are described as moderately deep, gravelly, imperfectly drained, yellow sandy loam over sandy clay loam. The subsoils are sodic (exchangeable sodium greater than 5%), making these soils pulverulent (powdery or dusty) when subjected to traffic movement and prone to water erosion. These soils support eucalypt woodland vegetation.

Organosols

The Mullalgah soil family was observed on footslopes fringing estuary mangrove swamps in the onshore development area. These deep soils are formed on marine sediments with organic (peaty) A horizons, and acidic groundwater discharge leaves a layer of iron floc on the surface.

Hydrosols

The Euro soil family is found on intertidal flats that experience regular saline tidal inundation under mangrove vegetation. Organic materials from mangrove debris dominate the surface layers to depths of 0.5 m or more. These soils pose a high ASS risk because there can be bacterial reduction of sulfates under anaerobic conditions.

The Maand soil family is found on supratidal flats that are bare of vegetation except for halophytes. Tidal inundation in these areas is infrequent (spring tides) but a saline water table is present at shallow depths. These soils are shallow to moderately deep, non-gravelly, poorly drained marine muds.

Podosol–tenosol complexes

The Rinamatta soil family is found on sandy dunes at the coastal margins of the onshore development area. These soils are described as deep, non-gravelly, well-drained siliceous sands. At the foot of dunes adjacent to tidal swamps, podosols with subsoil organic-aluminium compound accumulation occur. Weakly developed B horizons higher in the dune sequence are typical of tenosols. These soils are prone to wind and wave erosion when surface cover is removed and are sensitive to disturbance by traffic.

The soil families represented in the onshore development area are presented in Figure 3-33, and generally follow similar boundaries to the vegetation communities of the area (described in Section 3.4.8 *Vegetation communities*). A summary of the key factors affecting soil fertility for each soil family is provided in Table 3-10.

Table 3-10: Environmental assessment of soil families

Soil family	PASS	ASS	Pulverulence	Water erosion	Wind erosion	Fertility
Blaydin	No	No	Moderate	Low	Low	High
Hotham	No	No	High	High	Moderate	Low
Koolpinyah	No	No	Very high	High	Moderate	Low
Mullalgah	Low	Moderate	Moderate	Low	Low	Low, waterlogged, saline
Euro	Very high	Low	Low	Low	Moderate	Low, waterlogged, saline
Maand	Low	Low	Low	Low	Low	Low, waterlogged, saline
Rinamatta	Low	Low	Low	Moderate	High	Low, saline

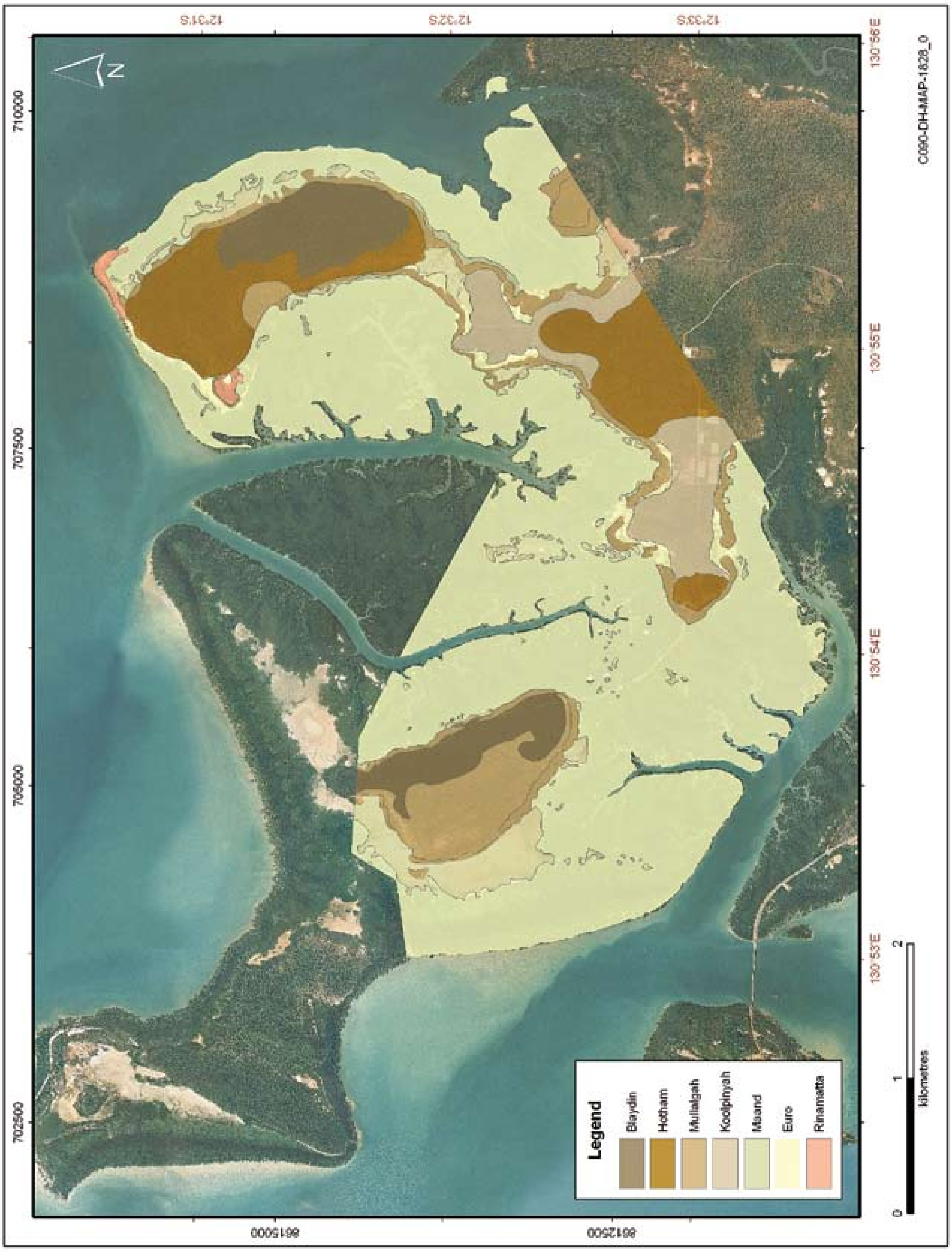


Figure 3-33: Soil families of the onshore development area

Soil chemistry

Previous soil sampling in the Northern Territory has suggested that arsenic in Cretaceous sediments can occur at relatively high levels in the surface 2 m, these levels being above the generic guidelines for contamination risk assessment (DoR 2009b). This situation occurs in deeply weathered lateritic terrain where silicate weathering reduces rock volume over geological time, leading to the residual concentration of heavy metals. However, metals are bound tightly to iron and aluminium sesquioxides in the natural environment and bioavailable fractions tend to be very low (Ng et al. 2003).

Soil-chemistry parameters in the onshore development area, including pH, salinity, extractable metals concentration, organic carbon content, nutrient content and potential ASS risk, were assessed by URS in May 2008 (see Appendix 17). Potential ASS risks were recorded for most of the mangrove and swamp soils throughout the onshore development area and all soils in or near the tidal zone were saline and strongly acid.

The ASS risk was generally an order of magnitude higher in the subsoil than in the surface layers that were commonly characterised by sandy sediment with low organic matter content. Subsurface levels are typically dark-coloured silty clays, with high organic matter accumulation, reducing conditions, and a "rotten egg" odour indicative of hydrogen sulfide (see Appendix 17).

Extractable metal concentrations in the soils throughout the onshore development area were lower than generic environmental criteria (NEPC 1999). High organic carbon and major nutrient levels were recorded in surface soils in the onshore area (above the intertidal zone), suggesting high soil fertility. Copper and zinc trace-metal levels were deficient in soils in the onshore area and all the soils were found to be sodic (see Appendix 17).

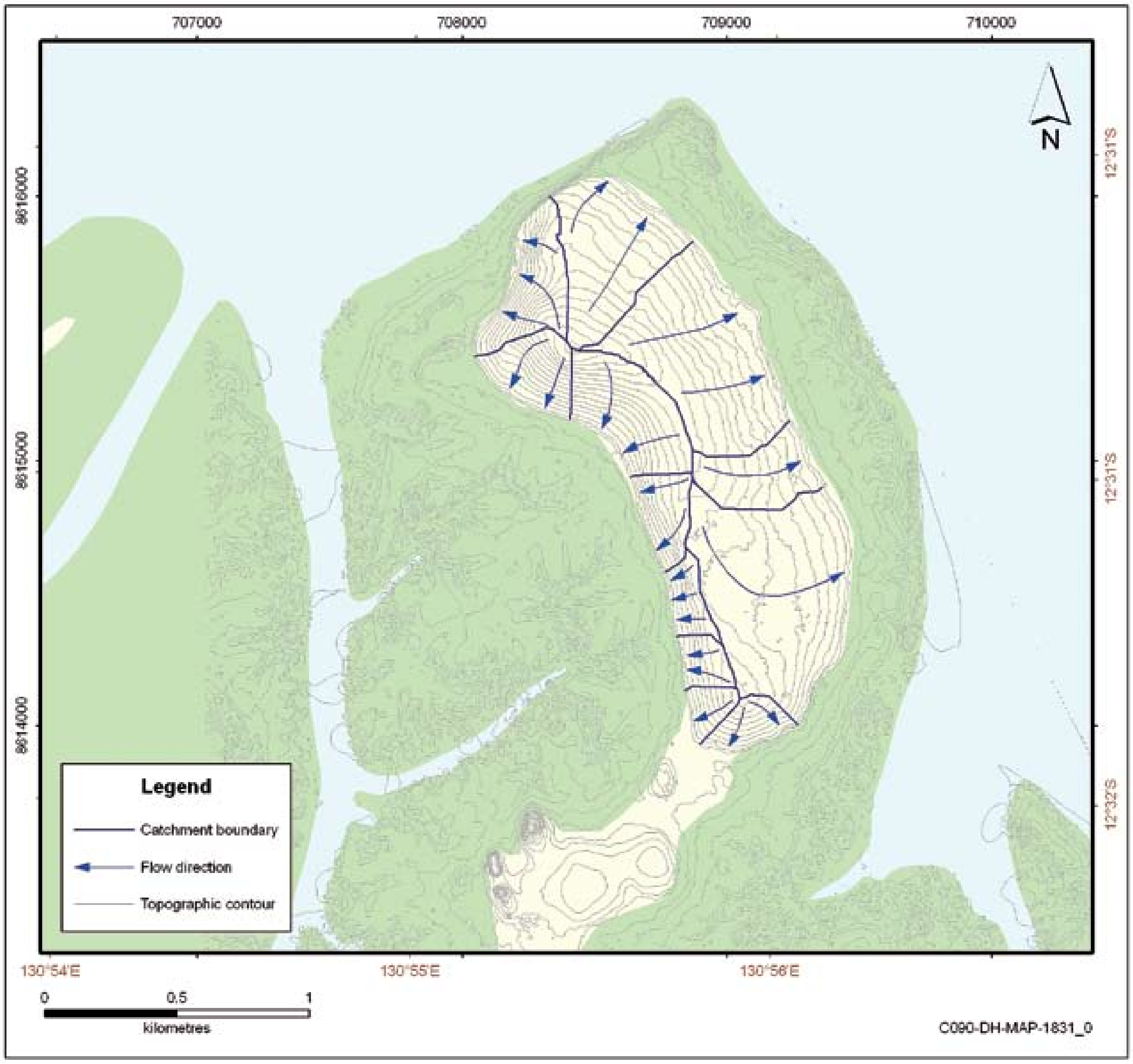


Figure 3-34: Topography and surface-water catchment boundaries of Blaydin Point

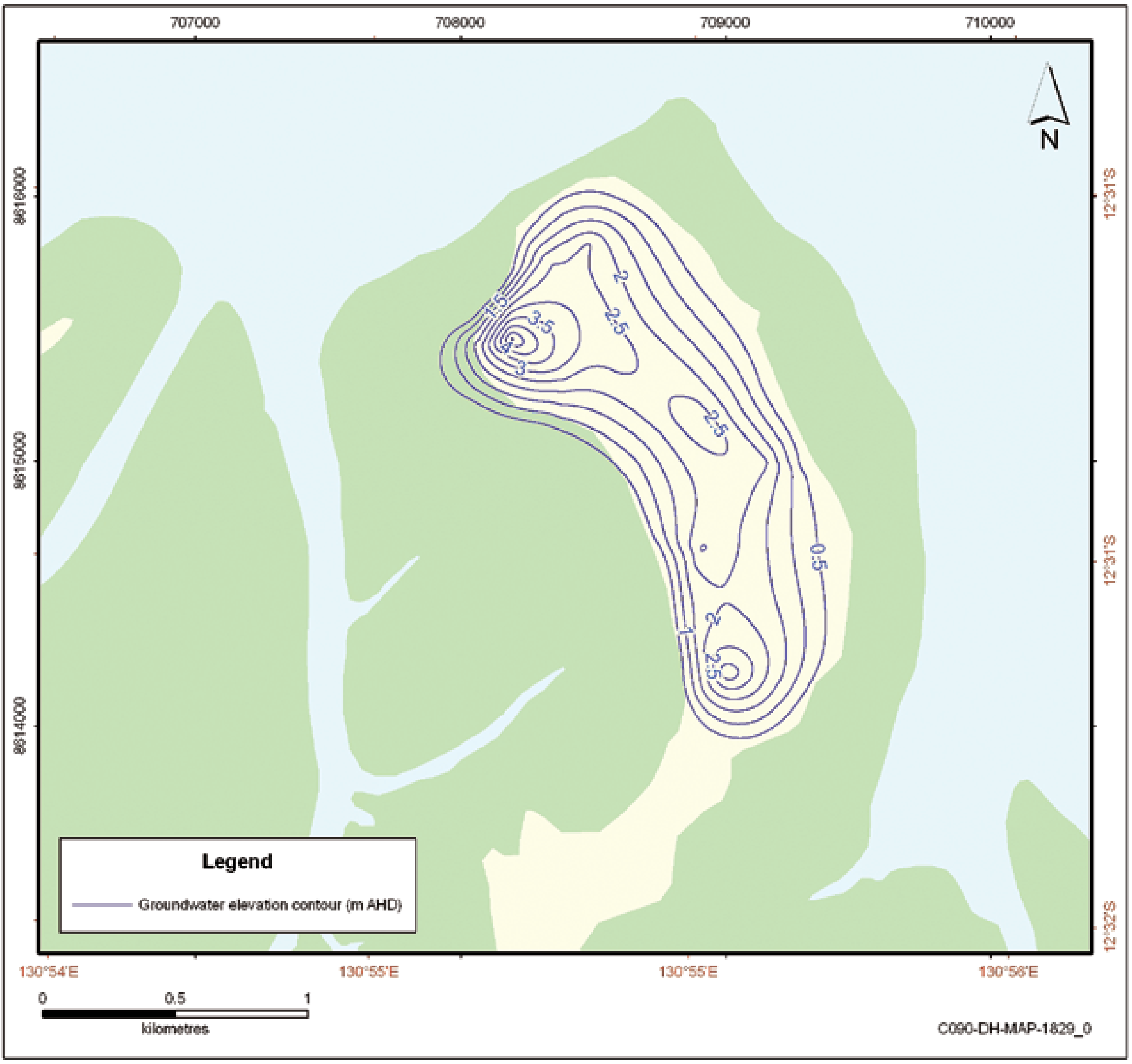


Figure 3-35: Groundwater elevation contours (metres AHD) at Blaydin Point

3.4.5 Seismicity

Distant earthquakes near Indonesia can affect Darwin, although there have been no recorded tsunamis impacting Darwin's shores despite its relative proximity to the convergent margin between the Australian and South-East Asian tectonic plates. Seismically, the northern part of Australia and the Darwin region are comparatively stable and large-magnitude earthquakes are rare. Most of the earthquakes felt in the Darwin region occur approximately 500–600 km to the north along the convergent plate margin near the Banda Sea to the north-east of Timor (Nott 2003).

The greatest earthquake intensity felt in Darwin during historical times was from the M_s 7.3 earthquake that occurred at a depth of 16 km, 530 km north of Darwin on 7 October 1960 (Vanden Broek 1980). Damage to concrete fixtures, toilet fixtures, and walls occurred as a result of this event. An earthquake with a similar intensity in the Darwin area can be expected at least once every 50 years. Buildings most at risk in the immediate Darwin city area are those that are built upon soft alluvial foundations where liquefaction and amplification of seismic waves could occur. The specific geology of an area, therefore, will determine the extent of damage during rare events of this magnitude.

3.4.6 Surface water

The existing surface-water regime at the onshore development area was characterised in field studies conducted by URS in July 2008 (URS 2009e). The results of these are summarised below. (The full URS technical report is provided in Appendix 18.)

The Blaydin Point peninsula is generally flat and varies only 10 m in topography over its area. The site can be divided into approximately 12 surface-water catchments as shown in Figure 3-34.

Throughout the onshore development area the surface soil layer rapidly absorbs water from rainfall when the soil profile is dry, such as at the end of the dry season and into the beginning of the wet season. After regular rainfall the surface layer becomes saturated and overland water flows occur. Because of the low undulating topography, surface flows are most likely to consist of non-turbulent sheet flow over the soil surface. Where water accumulates at the outer edges of Blaydin Point, surface-water flow is likely to become increasingly turbulent and occupy temporary drainage channels. These channels become the ephemeral sections of the tributary creeks that feed into Lightning Creek to the west and East Arm to the east.

The vegetation distribution across the onshore development area also provides insight into the surface-water and groundwater regimes. The central highland portion of the peninsula has mixed species of *Melaleuca* forming low to open woodland with dense sedges and grasslands. Generally, melaleucas can withstand waterlogging (Wong, Wong & Baker 1999) and their presence suggests that the water table is likely to rise close to the ground surface in this part of the onshore development area. Vegetation communities are described in more detail in Section 3.4.8.

3.4.7 Groundwater

The existing groundwater regime at Blaydin Point was characterised in field studies conducted by URS in July 2008. Ten groundwater monitoring bores were developed and cased with polyvinyl chloride (PVC) pipe to enable measurements of groundwater levels. At four sites a confining layer of clay or siltstone was encountered and an extra shallow bore installed to monitor any potential perched aquifers. Pump testing of each bore was undertaken to improve the understanding of hydraulic characteristics of the aquifers across Blaydin Point. The results of the study are summarised below, while the complete technical report is provided in Appendix 18.

Groundwater flows

The most prominent aquifer on Blaydin Point occurs in the sand and gravel horizons of the Bathurst Island Group. A gravel layer is present at the interface between the sediments and bedrock. Sediments overlying the gravel horizon are composed of sand, clay and silt. It is possible that semi-confined conditions may exist in this aquifer.

The underlying bedrock is variably weathered across Blaydin Point and represents the Burrell Creek Formation. It contains minor weathered or fractured rock aquifers. The bedrock elevation is generally below 0 m AHD and is deepest at –15 m AHD.

Groundwater levels across Blaydin Point generally follow the topography and are highest in the north-west area, at 5.06 m AHD, and lowest at the coastal edges (see Figure 3-35).

Seepage pathways beneath the onshore development area include the following:

- transmissive sand aquifers
- weathered bedrock
- fractures and faults in fresh bedrock.

As transmissive aquifers are located below sea level, water flows entering the water table at Blaydin Point could migrate both laterally and vertically, and propagate outward, potentially discharging to Darwin Harbour. The rate of this groundwater movement depends on the hydraulic conductivity and porosity of the media in the flow path and the hydraulic gradient. For the onshore development area, the groundwater velocity is estimated to be 0.08–1.2 m/d, or 29–438 m/a (see Appendix 18).

Groundwater quality

Groundwater under the central, elevated parts of the onshore development area is of low salinity and of a similar quality to rainwater and drinking water. Groundwater salinity increases to brackish or saline towards the edges of the Blaydin Point peninsula, especially under the mangrove vegetation. Groundwater salinity contours, measured as total dissolved solids (TDS) are presented in Figure 3-36.

The pH levels of groundwater in Blaydin Point are neutral to slightly acidic and vary between 4.7 and 6.3. Dissolved salts consist mainly of sodium chloride, although calcium carbonate is also present in high concentrations at some areas around the onshore development area.

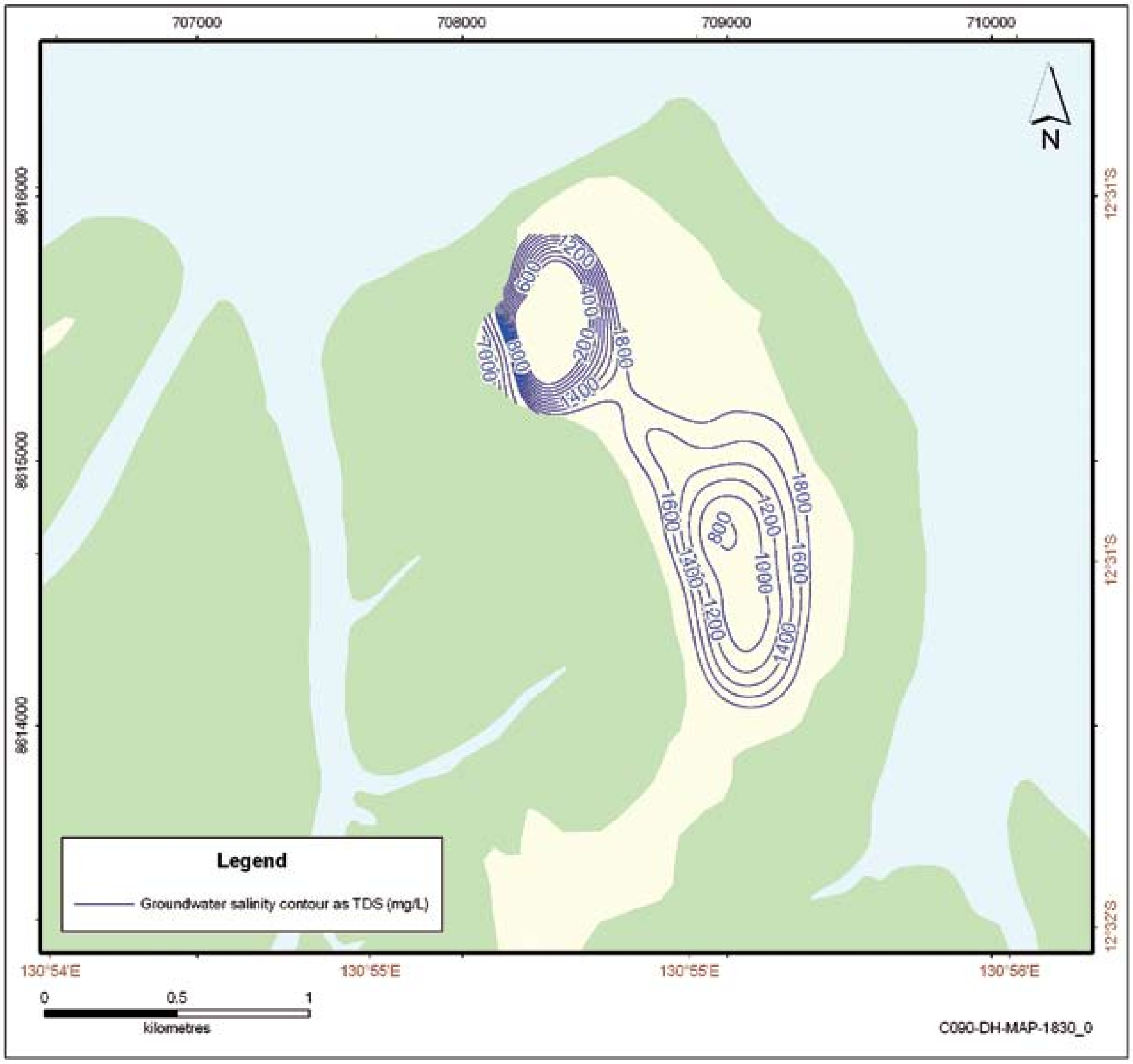


Figure 3-36: Groundwater salinity contours at Blaydin Point

Metals concentrations in groundwater throughout Blaydin Point were compared with the ANZECC and ARMCANZ (2000a) trigger-value guidelines for toxicity for fresh and marine water. Arsenic, chromium, lead, mercury and vanadium levels were all below the trigger values and in some cases were below the laboratory detection limit.

The groundwater presented copper and zinc levels higher than the ANZECC and ARMCANZ marine water trigger values in most of the bores tested. Cadmium, copper, manganese, nickel and zinc were higher than the ANZECC and ARMCANZ (2000a) freshwater trigger values at a number of bores across the onshore development area (see Appendix 18).

3.4.8 Vegetation communities

Darwin Coastal Bioregion

The Darwin Coastal Bioregion contains some of the most extensive and diverse floodplain systems in northern Australia, associated with the lower reaches of many large rivers. There are also substantial tracts of mangroves, patches of monsoon vine forest (also known as "dry rainforest"), and widespread areas of eucalypt tall open forest, typically dominated by Darwin woollybutt (*Eucalyptus miniata*) and Darwin stringybark (*E. tetrodonta*) (DEWHA 2009e). The various vegetation communities found in the bioregion, and their respective areas, are presented in Table 3-11.

Table 3-11: Area of present vegetation communities in the Darwin Coastal Bioregion (*c*.1997)

Vegetation community	Area (ha)	Proportion of total area (%)
Cleared or modified native vegetation	85 368	3.0
Monsoon vine forest	6 964	0.2
Eucalyptus open forest	1 157 372	41.3
Eucalyptus woodlands	4 300	0.2
Melaleuca forest and woodlands	254 548	9.1
Tropical eucalyptus woodland and grasslands	408 476	14.6
Other shrublands	72 064	2.6
Tussock grasslands	6 420	0.2
Other grasslands, herblands, sedgelands and rushlands	621 756	22.2
Chenopod shrub, samphire shrub and forb lands	121 976	4.4
Mangroves, tidal mudflat, samphire and bare areas, claypan, sand, rock, salt lakes, lagoons and lakes	61 620	2.2
TOTAL	2 800 864	100.0

Source: DEWHA 2009e.

The most widespread vegetation community in the region is eucalypt woodland, covering 41% of the land mass. “Woodland” is characterised by fairly sparse foliage cover (less than 30%) with an understorey of perennial and annual grasses (NRETAS 2007d). This vegetation type occurs on the upper slopes and is dominated by stringybark (*Eucalyptus tetrodonta*) and woollybutt (*E. miniata*). Common understorey species include the cycad *Cycas armstrongii*, the sand palm *Livistona humilis* and the pandanus *Pandanus spiralis*, with a perennial grass layer of *Sorghum* species. The annual wet season is characterised by a flush of growth in this understorey layer, while grasses senesce completely in the dry season and support frequent fires. Introduced grass species further enhance the intensity and frequency of this fire regime (DHAC 2003).

Lower in the landscape profile, patches of monsoon vine forest or dry rainforest occur in the bioregion. While this vegetation type represents only a small proportion of the total regional area, it contains a diverse flora and its various flowering and fruiting plant species provide food and habitat for a wide variety of animals. The monsoon vine forest is consequently considered to be of high conservation value (Blanch, Rea & Scott 2005).

Monsoon vine forest is associated with permanent water springs and supports a distinctive community of evergreen trees, with a closed canopy 20–25 m tall. Tree species typically include *Carpentaria acuminata*, *Acacia auriculiformis* and *Calophyllum soulattri* (GHD 2009). The mid-storey has reduced light levels and often comprises juvenile canopy trees and vines.

Many monsoon vine forest species are fire-sensitive, restricting the vegetation type to areas associated with permanent water or fire-protected rocky outcrops (Metcalfe 2002).

Other common lowland vegetation types in the Darwin Coastal Bioregion include paperbark (*Melaleuca* spp.) forest, grasslands and heathlands. The alluvial plains and swamps in the region are regularly inundated during the wet season and are dominated by various sedges and rushes, particularly of the genera *Eleocharis*, *Fimbristylis* and *Cyperus*, and the grasses *Pseudoraphis spinescens*, *Hymenachne acutigluma* and *Oryza meridionalis.* During the dry season these areas dry out and much of this dense vegetation dies or exists as underground tubers (DHAC 2003).

The intertidal mudflats of the greater Darwin Harbour area between Charles Point and Gunn Point carry extensive tracts of mangroves covering 27 350 ha, which constitutes 44% of the mangrove community in the bioregion, and about 5% of the total mangrove area of the Northern Territory. About 80% of this area (20 450 ha) occurs in the “inner” Harbour, between Sadgroves Creek (near Darwin’s CBD) and Mandorah. As of 2004, around 400 ha (2%) of these inner-Harbour mangroves had been cleared for residential, industrial and infrastructure developments, such as East Arm Wharf (WMB 2005).

This mangrove vegetation community is known for its species richness, containing 36 of the 50 mangrove species known worldwide. The most common mangrove species in Darwin Harbour are *Rhizophora stylosa*, *Ceriops tagal*, *Sonneratia alba*, *Bruguiera exaristata*, *Avicennia marina* and *Camptostemon schultzii.* The mangrove species occur in distinctive vegetation “assemblages”, of which 11 have been identified in Darwin Harbour (Figure 3-37) (Brocklehurst & Edmeades 1996; WMB 2005).

The structure and composition of mangrove assemblages vary according to tidal conditions and geomorphology. As shown in Figure 3-37, in some areas the mangrove zone exists in a narrow band, while other areas support dense forests up to 20 m in height across a wide intertidal zone, with defined strips of different mangrove assemblages reflecting the length of tidal inundation and salinity (DHAC 2003).

Mangroves form a valuable part of the marine ecosystem by producing large amounts of organic matter and nutrients, utilised by animals such as crustaceans and fish. Many fish and prawn species, including species significant to recreational and commercial fisheries, utilise the mangroves as spawning grounds and nursery habitat (WMB 2005). Most of the mangrove tracts surrounding Darwin Harbour are zoned for “conservation” under the Northern Territory Planning Scheme (DPI 2008), recognising the biodiversity value of this vegetation community.

Onshore development area vegetation communities

Vegetation communities were identified in the onshore development area using publicly available vegetation mapping (Brock 1995; Brocklehurst & Edmeades 1996) and aerial photography. Verification of this preliminary mapping was undertaken through field surveys conducted by GHD in October 2007 and May 2008. A total of 17 quadrats, each 50 m × 50 m, were surveyed throughout the onshore development area to record plant species and vegetation community structure (e.g. landscape position, canopy cover, ground cover, and stand basal area).

The resulting vegetation distribution is presented in Figure 3-38 and the identified vegetation communities are broadly described in Table 3-12. Photographs of some of the major vegetation communities surveyed are shown in figures 3-33 to 3-35. The full technical report for the flora study (GHD 2009) is provided in Appendix 16 to this Draft EIS.

Significant ecological communities

No ecological community found at the onshore development area is a listed threatened ecological community under the EPBC Act.

However, both the monsoon vine forest and the intertidal mangrove communities are considered to have conservation significance in the context of the Darwin Harbour region and the Northern Territory. Both of these communities are utilised as feeding or breeding areas by a wide range of vertebrate and invertebrate animals.

3.4.9 Plants in the onshore development area

As described in Section 3.4.8, plant surveys were conducted in the onshore development area by GHD in October 2007 and May 2008, representing dry-season and wet-season vegetation conditions respectively (see Appendix 16). Seventeen quadrats of 50 m × 50 m were included in the survey, which recorded all plant species and their distribution within each quadrat.

Not all plant samples could be identified to species level in the field because of a lack of sufficient diagnostic material (e.g. flowers and seeds). Where possible, samples were analysed and identified by the Northern Territory Herbarium, but in some cases identification to species level was not possible.

The following numbers of species were recorded in the field survey:

- 196 species positively identified to species level
- 28 species positively identified to genus level (species unclear)
- 21 species positively identified to family level (genus and species unclear)
- 5 species where no positive identification was possible.

Of the species that were positively identified, 109 represent new records for Middle Arm Peninsula and its surrounds. This is a reflection of the relative lack of botanical studies undertaken in the area. A total of 177 species was recorded in wet-season surveys, including 23 from the family Poaceae, 11 from the family Myrtaceae and 9 from the family Fabaceae. Fewer species were recorded in the dry season survey (89 in total), with the Myrtaceae, Sterculiaceae and Euphorbiaceae being the most commonly recorded families (with 9, 6 and 5 species respectively) (see Appendix 16).

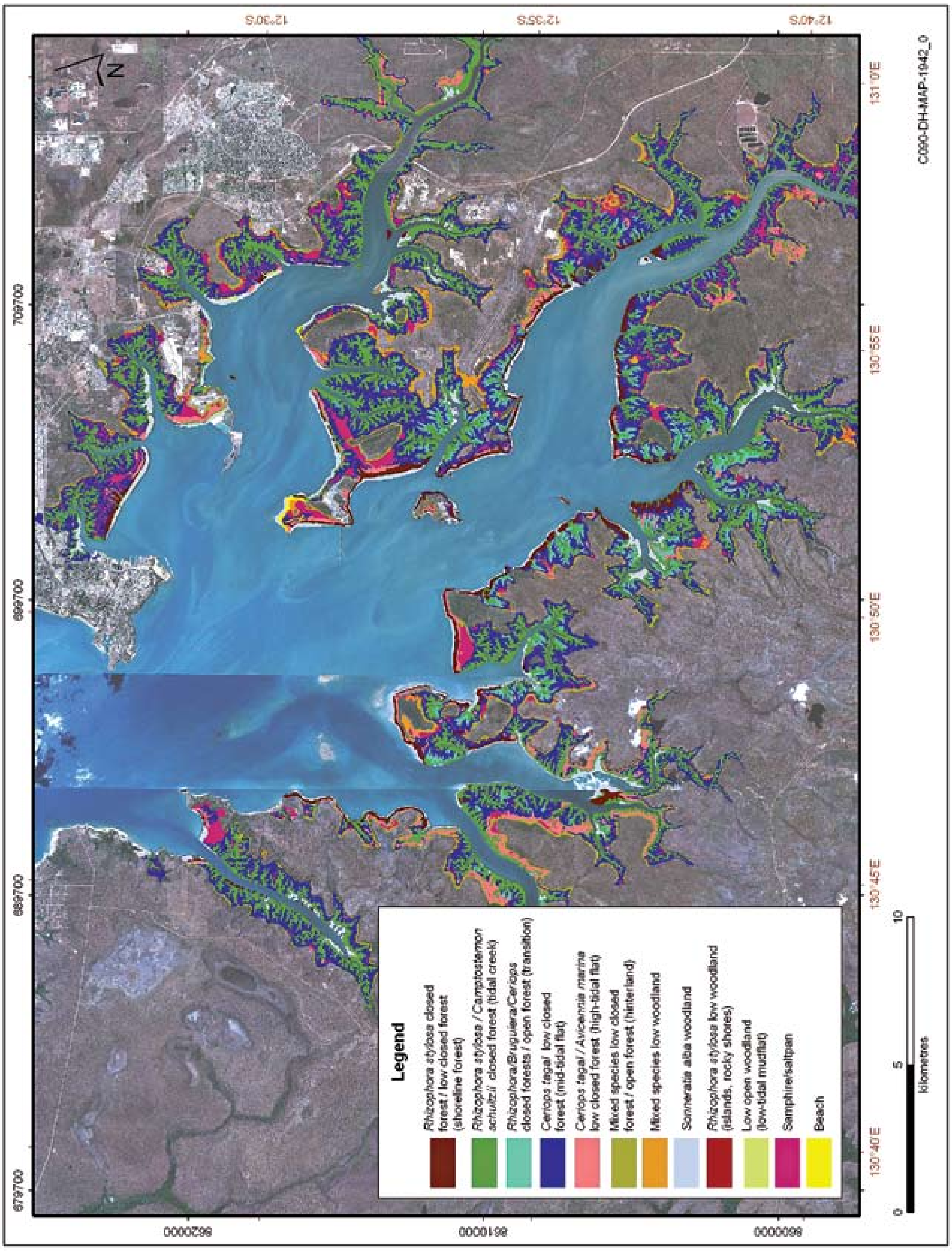


Figure 3-37: Mangrove distribution and zonation around Darwin Harbour

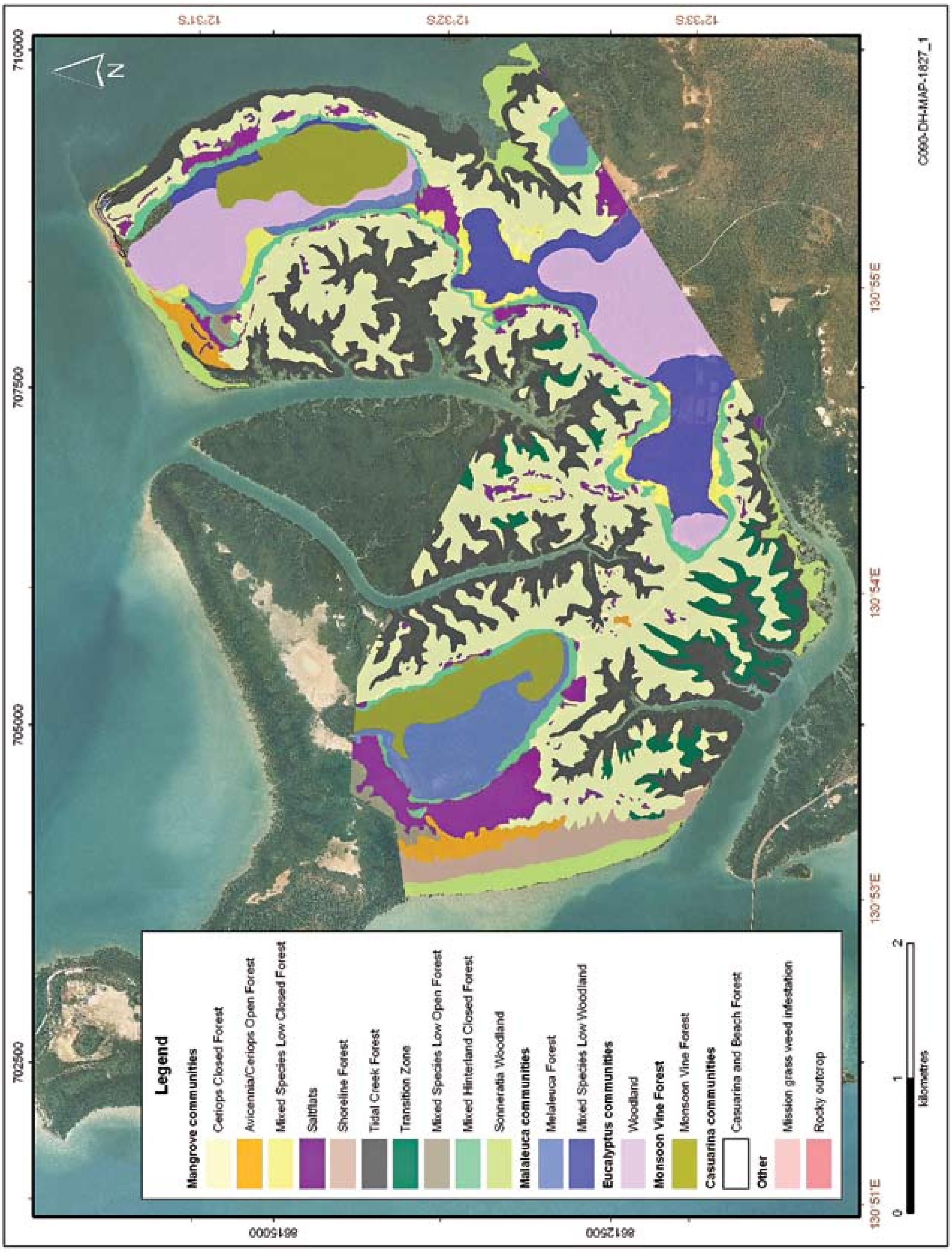


Figure 3-38: Vegetation communities of the onshore development area

Table 3-12: Descriptions of vegetation communities in the onshore development area

Vegetation community	Description
Mangrove communities	
Ceriops closed forest	*Ceriops australis* low closed forest.
Avicennia–Ceriops closed forest	*Avicennia marina – Ceriops australis* closed forest (see Figure 3-41).
Mixed species low open forest	*Melaleuca leucadendra – Acacia auriculiformis* open forest with a dense mid-storey characteristic of coastal monsoon vine forest such as *Canarium australianum* and *Strychnos lucida.*
Sparse samphire shrubland	Salt flats with sparse samphires such as *Tecticornia* (formerly *Halosarcia*) *halocnemoides* with low, very sparse mangrove species.
Rhizophora closed forest	*Rhizophora stylosa* closed forest.
Rhizophora–Sonneratia closed forest	*Sonneratia alba – Rhizophora stylosa – Camptostemon schultzii* closed forests in tidal creeks.
Transition zone	Preliminarily mapped as a transition zone between seaward mangrove elements (*Rhizophora–Sonneratia*) and mangroves in the higher end of the tidal level (*Ceriops australis*).
Corymbia bella – Melaleuca leucadendra transitional open forest	Transitional open forest between terrestrial vegetation communities and mangrove communities. Dominated by *C. bella* and *M. leucadendra* and contains elements of woodland and terrestrial forest communities.
Sonneratia closed forest	*Sonneratia alba* closed forest at the seaward margin of mangrove communities.
Melaleuca communities	
Mixed species low open woodland	*Melaleuca nervosa*, *M. viridiflora*, *Grevillea pteridifolia* and *Lophostemon lactifluus* mixed species low woodland to low open woodland. Dense to mid-dense sedgeland–grassland which includes *Leptocarpus spathaceus*, *Eriachne burkittii*, *E. triseta* and *Pseudopogonatherum* spp.
Melaleuca open woodland	*Melaleuca leucadendra*, *M. viridiflora* open woodland with *Acacia auriculiformis* and elements of monsoon vine forest such as *Flagellaria indica*.
Eucalyptus community	
Eucalyptus miniata – E. tetrodonta woodland	*Eucalyptus miniata – E. tetrodonta* woodland to low woodland, with a mixed-species mid-stratum including *Cycas armstrongii* and a grassland understorey (see Figure 3-39).
Monsoon vine forest	
Closed monsoon vine forest	Mixed species closed monsoon vine forest associated with permanent moisture. Closed canopy 20–25 m tall dominated by evergreen species, including *Acacia auriculiformis*, *Calophyllum soulattri*, *Carpentaria acuminata*, *Horsfieldia australiana* and *Syzygium nervosum* (see Figure 3-40).
Casuarina community	
Casuarina and beach open woodland	Beach vegetation on areas of sand including some mangrove species such as *Bruguiera exaristata* and *Ceriops australis*, also with *Ipomoea pes-caprae*, *Thespesia populneoides* and *Sesuvium portulacastrum*.

Figure 3-39: Eucalypt woodland at Blaydin Point

Figure 3-40: Monsoon vine forest at Blaydin Point

Figure 3-41: Mangroves and mudflat at the edges of Blaydin Point

Flora species of conservation significance

The cycad *Cycas armstrongii* is listed as vulnerable under the TPWC Act, and was recorded in the field survey of the onshore development area. This species is endemic to the Northern Territory and is locally abundant across the western Top End region, the Cobourg Peninsula and the Tiwi Islands. It is considered vulnerable in conservation terms as only a very small proportion of its distribution range occurs in conservation reserves (approximately 1%), and because its preferred habitat of deep loamy soils is also favoured by agriculture, horticulture and forestry and is therefore at risk of land clearing.

After land clearing, the most significant threat to *C. armstrongii* is fire. Adult stems suffer mortality in fires with higher-than-average temperatures, such as those fuelled by the high litter loads produced by introduced grass species such as gamba grass (*Andropogon gayanus*) and mission grass (*Pennisetum polystachion*) (GHD 2009). Fire also reduces seed viability.

Cycas armstrongii was observed in the study area throughout the *Eucalyptus miniata – E. tetrodonta* woodland community.

No plant species listed under the EPBC Act were recorded in field surveys of the onshore development area, and none appear on the public database of threatened species for the Blaydin Point area (see Appendix 16).

3.4.10 Weeds

A survey of existing weeds (introduced plant species with the potential to become invasive) was undertaken in the onshore development area by GHD during July 2008 (dry season). The survey concentrated on roads, tracks and areas of historical and present-day soil disturbance on Blaydin Point and Middle Arm Peninsula. Weeds were identified and mapped, and assessed for the extent of their infestations and their potential to spread further. The full results of this survey are provided in Appendix 16.

A total of 12 weed species were recorded during the survey, listed in Table 3-13. Four of these—hyptis, lantana, gamba grass and mission grass—are listed as declared weeds under the *Weeds Management Act 2001* (NT), and three are also weeds of significance according to the Commonwealth list of “weeds of national significance”.

Table 3-13: Weeds recorded in the onshore development area

Species name	Family	Common name	Northern Territory status*	Commonwealth status
Andropogon gayanus	Poaceae	Gamba grass	Class B/C	–
Chloris inflata	Poaceae	Purpletop chloris	–	–
Crotalaria goreensis	Fabaceae	Gambia pea	–	–
Hibiscus sabdariffa	Malvaceae	Rosella	–	–
Hyptis suaveolens†	Lamiaceae	Hyptis, horehound	Class B/C	–
Lantana camara	Verbenaceae	Lantana	Class B/C	Weed of national significance
Melinis repens	Poaceae	Red Natal grass	–	–
Passiflora foetida	Passifloraceae	Stinking passion flower	–	–
Pennisetum pedicellatum	Poaceae	(none)	–	–
Pennisetum polystachion†	Poaceae	Mission grass	Class B/C	–
Scoparia dulcis	Scrophulariaceae	Scoparia	–	–
Stylosanthes viscosa	Fabaceae	Shrubby stylo, seca	–	–

Source: GHD 2009.

* Refers to the listing of declared weeds under the *Weeds Management Act 2001* (NT): Class A—to be eradicated; Class B—growth and spread to be controlled; Class C—not to be introduced to the Northern Territory.

† *Hyptis suaveolens* and *Pennisetum polystachion* were ranked 22nd and 46th respectively out of 71 weeds assessed as potential “weeds of national significance”. The inaugural list of weeds of national significance contains the top 20 ranked weed species (Thorp & Lynch 2000).

Overall, weeds in the onshore development area are not abundant and are mainly found along roads and tracks, as vehicles are important vectors for weed spread. There are a number of informal tracks leading from Wickham Point Road and Channel Island Road north through the natural vegetation to the coast at Blaydin Point—these may have been created as access roads for recreational camping and fishing. Weed species such as mission grass and red Natal grass were common along the roadsides but were not observed extending far into the vegetation away from the road, nor forming dense thickets in areas of abundant bare ground. These species were not colonising areas of bare ground away from the roadsides and none were observed growing on the salt flats and mangrove tidal areas along Wickham Point Road (GHD 2008a).

Other key weed infestations are in areas of previous land clearing and soil disturbance. One such area of around 11.5 ha is located on Middle Arm Peninsula south of Blaydin Point, where borrow pits were created during the construction of the Darwin LNG plant and associated roads and service corridors around five years ago. This area now contains a mixture of native and introduced plant species, bare ground and depressions that hold water during the wet season. Introduced vegetation in this clearing is dominated by mission grass, which forms dense thickets up to 3 m tall, excluding almost all other vegetation. Hyptis is also scattered throughout this clearing.

A second cleared area of around 1.9 ha is located at the intersection of Wickham Point Road and the access track to the borrow pits. This area has been affected by mounding and excavation earthworks and now supports dense thickets of mission grass, as well as hyptis and stinking passion flower (GHD 2008a).

No weed species identified at the onshore development area is unique to Middle Arm Peninsula, and most are widespread throughout the Darwin Coastal Bioregion. The weed species of most concern to the local vegetation communities are mission grass, gamba grass and hyptis because of their potential to spread rapidly and to alter the ecology of the natural vegetation.

Mission grass and gamba grass form dense thickets that can support excessive fire frequencies and intensities that alter the vegetation structure of the northern savannahs, including the tree layer (NTPFES 2003). They are also prolific seeders—large quantities of seed were observed in dense mats underneath mission grass in the onshore development area (GHD 2009).

Hyptis is known to be an aggressive invader of native vegetation and is a well-established weed of the roadsides of the Top End. Individual hyptis plants were observed across the onshore development area, suggesting that there is potential for spread from roadsides outwards, through the lower storey of the woodlands. Hyptis is easily spread as the persistent spiny calyx enclosing the seeds adheres readily to human clothing and to the fur of animals and can also become embedded in the dust and mud coatings of vehicles (GHD 2009).

3.4.11 Terrestrial animals

Darwin Coastal Bioregion

The broader Top End of the Northern Territory supports a wide variety of vertebrate and invertebrate animals, with species richness increasing in the northern high rainfall areas. In comparison with high-endemism areas in the Northern Territory such as the Arnhem Plateau and MacDonnell Ranges bioregions, the fauna of the Darwin Coastal Bioregion has a relatively low level of endemism.

Most mammal species in the Darwin Coastal Bioregion are nocturnal and relatively inconspicuous. Mammals known to inhabit the bioregion include the northern quoll (*Dasyurus hallucatus*), the northern brown bandicoot (*Isoodon macrourus*), the northern brushtail possum (*Trichosurus vulpecula arnhemensis*) and the agile wallaby (*Macropus agilis*) (GHD 2009; URS 2002).

There is a rich diversity of bird species in the bioregion, although few of these species are endemic. Birds local to the area include a variety of raptors (kites, goshawks, falcons and eagles), kingfishers, doves, lorikeets, cockatoos, honeyeaters and terns (GHD 2009).

Migratory birds are common in the Darwin Coastal Bioregion, where the coastline and wetlands support large numbers of various species of waders or shorebirds. These birds migrate to the northern hemisphere to breed during the northern summer, and may also travel through the Northern Territory to southern Australia for the southern summer period. Other birds such as the koel (*Eudynamys scolopacea*), dollarbird (*Eurystomus orientalis*) and rainbow bee-eater (*Merops ornatus*) make annual migrations to Indonesia and other parts of south-eastern Asia (NRETAS 2007e).

Lizards, particularly skinks, dominate the reptile fauna of the Northern Territory. The saltwater crocodile (*Crocodylus porosus*) is found in the bioregion, along with a wide variety of snakes including the olive python (*Liasis olivaceus*) and brown tree snake (*Boiga irregularis*).

Amphibians occur throughout freshwater environments—the green tree frog (*Litoria caerulea*), the brown tree frog (*L. rothii*) and the dwarf tree frog (*L. bicolor*) are examples of local species (URS 2002).

Fauna conservation and species richness in the Darwin Coastal Bioregion is influenced by several alien "pest" animal species, including the cane toad (*Bufo marinus*), feral cat (*Felis catus*) and feral pig (*Sus scrofa*). These threaten native animal populations through predation and competition for food and habitat (NRETAS 2007e).

Habitats of the onshore development area

Previous fauna surveys on Middle Arm Peninsula have identified a total of 289 vertebrate species in the area, according to the NRETAS survey database. These include 26 mammal, 224 bird, 33 reptile and 6 amphibian species.

A survey of terrestrial vertebrate fauna was carried out at the onshore development area by GHD to characterise the existing features of the area. The survey effort included sampling during both late dry season (late October 2005) and late wet season (early May 2008) conditions. The survey sites utilised for the fauna survey were a subset of the sites developed for the vegetation survey (discussed in Section 3.4.8) and included a total of 13 quadrats of 50 m x 50 m. Systematic trapping was undertaken at each site over a period of three nights during each season, using pit traps, funnel traps, cage traps, Elliott traps and hair tubes. Bat surveys were conducted using echolocation calls for insectivorous bats (GHD 2009).

In total, 148 vertebrate species were recorded in the fauna survey, including 9 species of mammal (of which 4 were bats), 106 birds, 22 reptiles and 11 frogs. The results are summarised as follows, while the full technical report is provided in Appendix 16 to this Draft EIS (GHD 2009).

Results of the trapping program indicated that the major habitat types important to animal groups at the onshore development area are closely related to the vegetation communities presented in Section 3.4.8. The eucalypt communities and savannah woodlands are the more species-rich communities for animals, particularly birds.
The eucalypt savannahs occupy the largest proportion of the onshore development area, as they do of the Northern Territory. However, the significance of the observation of more species occurring in the savannahs is diminished as most vertebrate species have a diverse habitat requirement and would realistically exploit seasonal abundances of resources in particular habitats at particular times of year.

The probable dependence of species on multiple habitat types may be more important than an apparent bias towards the eucalypt savannah community (GHD 2009).

The monsoon vine forest habitat is structurally complex and provides habitat for a distinctive bird fauna, and theoretically for mammals. However, no small or mid-sized ground mammals (with the exception of the alien black rat) were recorded in the surveys (GHD 2009), and secondary traces (e.g. diggings and scats) were rarely observed. Unburnt monsoon vine forest patches with abundant leaf litter were present in the onshore development area despite recent fires, and still did not contribute any recordings of small mammals. This suggests that other factors may be influencing the presence of small ground mammals at the onshore development area (GHD 2009).

Across the onshore development area, areas of savannah woodland had high ground-level complexity and therefore tended to support a higher abundance and species richness of reptiles and birds. Mammals could also be expected to inhabit this community but, as described above, few were recorded in surveys of the onshore development area (GHD 2009).

The mangrove vegetation community provides habitat for mangrove-specialist bird species like honeyeaters, as well as for raptors. The intertidal areas around the onshore development area have low levels of understorey and ground-level vegetation and are therefore likely to offer only a low level of resources for vertebrate animals such as birds. However, it should be recognised that conditions and resources in this habitat type are more dynamic than in other vegetation types, fluctuating with tidal conditions. The tidal flats will periodically represent high-value foraging habitat for migratory wetland birds. The intertidal area can support few amphibians because of the lack of grass cover and the high salinity levels (GHD 2009).

A borrow pit in the onshore development area provides a seasonal waterbody that supported the majority of amphibians recorded during surveys, as well as some species of wetland and grassland birds (GHD 2009).

3.4.12 Protected species

As described in Section 3.2.8, the Commonwealth's EPBC Act provides a legal framework to protect and manage nationally and internationally threatened plants and animals. Threatened species may be listed under the EPBC Act in one of several categories depending on their population status (e.g. "critically endangered", "endangered", "vulnerable", and "conservation dependent"). In addition, a range of migratory terrestrial species are protected under the

EPBC Act as they are listed in international treaties and conventions for the protection of wildlife.

Threatened species in the Northern Territory are protected under the TPWC Act, and may also be classified in a range of categories (e.g. "critically endangered", "endangered", "vulnerable", "near threatened", "data deficient" and "not threatened in the Northern Territory").

None of the animal species recorded in field surveys of the onshore development area are listed as threatened under the TPWC Act or EPBC Act (GHD 2009). However, publicly available databases suggest that there are a number of threatened animal species that could potentially occur in and around the onshore development area. Those that are listed as "critically endangered", "endangered" or "vulnerable" are presented in Table 3-14. It is noted that other species with less critical conservation status may also occur in the onshore development area (see the full list provided in Appendix 16 to this Draft EIS).

In addition to Northern Territory and Commonwealth legislation, terrestrial animals that are considered to be under a global threat of extinction are listed on The IUCN Red List of Threatened Species, or may be protected by international treaties such as CITES or the Bonn Convention. Species protected by such conventions and laws and that may occur in the onshore development area are also noted in Table 3-14.

Some of the threatened species that may inhabit the onshore development area are described in more detail below.

Mammals

Northern quoll

The northern quoll (*Dasyurus hallucatus*) has been recorded across the Top End of the Northern Territory and as far south as Alexandria Station on the Barkly Tableland (central-eastern Northern Territory). In recent times the species has experienced a marked contraction in range that has been attributed to numerous potential causal factors including changes in fire regime, vegetation structure, disease and competition with feral cats. The decline of the northern quoll has been exacerbated by the recent arrival in the Northern Territory of the invasive cane toad *Bufo marinus*. Quolls that prey on the toads are killed by the poisons contained in the skin glands of the toads (GHD 2009).

Table 3-14: Protected terrestrial animal species that may be present in or near the onshore development area

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention	CITES#
Mammals						
Dasyurus hallucatus	Northern quoll	E	CE	LR (NT)	n.a.	–
Xeromys myoides	Water mouse (or false water-rat)	V	DD	V	n.a.	I
Birds						
Erythrotriorchis radiatus	Red goshawk	V	V	V	n.a.	II
Geophaps smithii smithii	Partridge pigeon (eastern)	V	V	(NT)	n.a.	–
Calyptorhynchus banksii	Red-tailed black-cockatoo	E	NT	(LC)	n.a.	–
Erythrura gouldiae	Gouldian finch	E	E	E	n.a.	–
Reptiles						
Varanus panoptes	Floodplain monitor	–	V	–	n.a.	II

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
CE = Critically Endangered; E = Endangered; V = Vulnerable; DD = Data Deficient; NT = Near Threatened.

‡ International—IUCN: The IUCN Red List of Threatened Species.
E = Endangered; V = Vulnerable; LR = Lower Risk; (NT) = Near Threatened; (LC) = Least Concern.

# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

n.a. = not applicable.

The northern quoll was previously recorded from savannah woodland and mangrove fringes at Middle Arm Peninsula. There are also 14 records of northern quolls at the onshore development area between 1990 and 2001. Despite the presence of suitable quoll habitat at Blaydin Point, no traces of the northern quoll were detected in recent dry- or wet-season surveys of the area. The cane toad is currently well established and occurs in most habitats at Blaydin Point. It is possible, therefore, that the quoll has experienced localised declines following the arrival of the toads. However, quolls are relatively secretive and can go undetected in trapping surveys, so the survey result should be considered inconclusive (GHD 2009).

Water mouse

The water mouse or false water-rat (*Xeromys myoides*) has not been recorded previously at the onshore development area and signs of its presence were not observed during recent surveys. If the species does utilise the area, the proposed removal of mangroves by the Project will have a relatively minor impact on its habitat availability, as similar habitat is available throughout Darwin Harbour and the Darwin Coastal Bioregion (GHD 2009).

Birds

Red goshawk

The red goshawk (*Erythrotriorchis radiatus*) occurs across much of northern Australia. It generally occurs in taller forests in high rainfall areas and preys mainly on medium-sized birds. The onshore development area does not appear to provide habitat characteristics ideal for red goshawk foraging or breeding. There are no historical records of the red goshawk in the onshore development area and the species was not recorded in recent surveys (GHD 2009).

Partridge pigeon

The partridge pigeon (*Geophaps smithii smithii*) is a medium-sized ground-dwelling pigeon that occurs across the top of the Northern Territory and the Kimberley. It is grey-brown in colour, with a red face and a white leading edge to the wing. The partridge pigeon may occur in large groups around water sources in the late dry season.

The species is listed as "vulnerable" under the TPWC Act and the EPBC Act. It occurs mainly in lowland eucalypt forests and woodlands with grassy understoreys. This species has not been recorded in the onshore development area and there is a lack of suitable habitat to support the species (GHD 2009).

Red-tailed black-cockatoo

The red-tailed black-cockatoo (*Calyptorhynchus banksii*) is endangered in some parts of Australia, mainly because of threats to its habitat by land clearing. However, the species is relatively common in low savannah woodland in the Darwin Coastal Bioregion and it was recorded 13 times in surveys of the onshore development area (GHD 2009). As woodland habitat is available throughout Middle Arm Peninsula and the broader region, the Project is unlikely to pose a threat to the distribution of this species.

Gouldian finch

The Gouldian finch (*Erythrura gouldiae*) is restricted to isolated areas mostly in the Northern Territory and the Kimberley. It is found in wooded eucalypt hills from February to October and in lowland drainages in the wet season. The onshore development area does not provide suitable habitat to support this species and it has not been recorded in the area (GHD 2009).

Migratory birds

Five raptor species were recorded in the onshore development area, including the brahminy kite (*Haliastur indus*), black kite (*Milvus migrans*), whistling kite (*Haliastur sphenurus*), brown goshawk (*Accipiter fasciatus*) and white-bellied sea-eagle (*Haliaeetus leucogaster*) (GHD 2009). All are listed migratory and/or marine species and are protected under the EPBC Act. All historical records from the area indicate that raptors are common in appropriate habitat across the Northern Territory and are generally classed as species of "least concern" under the TPWC Act.

Five species of migrant shorebirds were recorded during the surveys—the lesser sand plover (*Charadrius mongolus*), Pacific golden plover (*Pluvialis fulva*), eastern curlew (*Numenius madagascariensis*), whimbrel (*Numenius phaeopus*) and marsh sandpiper (*Tringa stagnatilis*). All are listed as protected marine and migratory species under the EPBC Act; however the onshore development area does not provide critical breeding or foraging habitat for these species. Shorebirds could be expected to pass through the onshore development area occasionally (GHD 2009). There are a large number of bird species that are listed as "migratory" or "marine" protected species under the EPBC Act and which have previously been recorded in the vicinity of the onshore development area. These include the little tern (*Sterna albifrons*), fork-tailed swift (*Apus pacificus*), grey-tailed tattler (*Tringa brevipes*) and ruddy turnstone (*Arenaria interpres*) (see Appendix 16 for a full list). The majority of these species are either unlisted or categorised as "data deficient" under the TPWC Act, and migrate internationally over very large ranges.

Chatto's (2000) investigation of major congregations of seabirds along the Northern Territory coast did not identify Darwin Harbour as a significant site for seabirds. Although a number of these species will occur from time to time in the vicinity of Blaydin Point and Middle Arm Peninsula, the area cannot be defined as "important habitat" for seabirds (GHD 2009).

Reptiles

Two monitors have been recorded at Blaydin Point in previous surveys—the sand goanna (*Varanus gouldii*) and the yellow-spotted monitor (*Varanus panoptes*). Neither species was recorded in recent surveys of the onshore development area. The yellow-spotted monitor is listed as "threatened" under the TPWC Act because its prey includes cane toads and it dies after ingesting the toad's toxins. Sand goannas may also be affected by the cane toad (GHD 2009).

3.4.13 Introduced animal species

The most widely occurring pest animal species recorded in surveys of the onshore development area was the cane toad (*Bufo marinus*). Cane toads were observed in savannah woodland, monsoon vine forest, mangrove fringes and in the vicinity of water-filled borrow pits, as well as on the road access tracks throughout the onshore development area (GHD 2009).

In addition, the black rat (*Rattus rattus*) was recorded in monsoon vine forest at Blaydin Point and the feral pig (*Sus scrofa*) was observed in mangroves; pig wallows and diggings were observed at the interface between mangroves and monsoon vine forest (GHD 2009).

3.4.14 Blaydin Point invertebrate fauna

Mangroves occupy most of the coastal margins of Darwin Harbour, as described in Section 3.4.8, and provide habitat for a range of invertebrate animals such as fiddler crabs, sesarmid crabs and polychaete worms.

To characterise the invertebrate fauna in the mangrove communities of the onshore development area, GHD conducted a field survey in December 2007. Nine transects were established in the intertidal zone around Blaydin Point and south of Wickham Point. Quadrats of 1 m^2 were developed every 20 m along each transect, and invertebrate animals (identified to species or species-group level), plants, burrows and pneumatophores were recorded in each quadrat. A total of 1231 individual animals from 13 species or species groups were recorded in the transect surveys, including fiddler crabs, sesarmid crabs, molluscs (*Telescopium telescopium* and *Terebralia semistriata*) and mudskippers (family Gobiidae) (GHD 2008b).

In addition, marine worms were assessed by digging up the top 0.1 m of mud from quadrats measuring 0.5 m x 0.5 m, and washing this through a sieve. All worms were removed and identified to the highest possible taxonomic level by the Museum and Art Gallery of the Northern Territory. A total of 39 animals belonging to 20 species were collected from the mud samples, including 17 from the class Polychaeta (GHD 2008b).

Previous studies of the distribution of invertebrate fauna in mangroves show that their zonation patterns can parallel the zonation of the mangrove plant species (Dames & Moore 1997). The patterns of distribution recorded in this survey conform to the general patterns previously reported for Darwin Harbour (GHD 2008b).

The invertebrate fauna at Blaydin Point was fairly uniform in animal abundance across all mangrove zones. Individual mangrove invertebrate species have unique patterns of habitat association, with all mangrove zones contributing significantly to the abundances of some species (GHD 2008b).

Surface fauna

Fiddler crabs exhibited a peak in abundance in the more seaward *Sonneratia*, *Sonneratia–Rhizophora*, and *Rhizophora* zones and were more abundant in areas with larger numbers of pneumatophores (GHD 2008b).

The abundance of sesarmid crabs was lower in the more landward areas such as salt flats. Among the mangrove zones sesarmid crab abundance did not vary greatly and was not influenced by the numbers of pneumatophores (GHD 2008b).

The mollusc *Telescopium telescopium* exhibited a peak in abundance in the *Rhizophora–Ceriops* and *Ceriops* zones. *Terebralia semistriata* showed a similar distribution and was also abundant in the *Ceriops* and *Avicennia* zones (GHD 2008b). Irrespective of mangrove zone, *Telescopium telescopium* and *Terebralia semistriata* were more abundant in areas with more species-rich vegetation (i.e. transition zones).

Mudskippers were more abundant in the *Sonneratia*, *Sonneratia–Rhizophora*, and *Rhizophora* zones, and preferred areas with large numbers of pneumatophores.

Polychaete worms

Species richness and abundance in polychaete worms increased towards the seaward margins around Blaydin Point. The mudflat–*Sonneratia* zone at Blaydin Point had the greater species richness and abundance of polychaete worms and the more equitable distribution of individuals among species. The composition of the fauna of the *Rhizophora–Ceriops* zone was slightly different from that of the mudflat–*Sonneratia* zone (GHD 2008b).

3.4.15 Biting insects

Two groups of biting insects are common in the area around Darwin. These are the biting midges of the family Ceratopogonidae and the mosquitoes of the family Culicidae.

Ceratopogonid biting midges can be considerable pests within a few kilometres of the coast in the Northern Territory, with the highest numbers occurring within 1.5 km of mangrove communities (Shivas & Whelan 2001). These insects can cause painful bites, while some people experience secondary effects such as intense itching, infection and scarring from scratching.

Mosquitoes are notable, of course, for their nuisance value to humans but they are also a potential public health problem in the Northern Territory because of their role as vectors of a number of viruses causing human diseases. These include the Murray Valley encephalitis virus, the Kunjin virus, the Ross River virus and the Barmah Forest virus (Medical Entomology Section 2009).

In order to characterise the existing populations of biting insects in the onshore development area, staff of the Medical Entomology Section (from the Northern Territory Government's Centre for Disease Control) conducted surveys in October and December 2007. Sampling was conducted using encephalitis virus surveillance traps baited with carbon dioxide, set overnight in six locations in the onshore development area. All survey sites were located above the high-water mark, inland of the intertidal mangrove zone. Trapped mosquitoes and biting midges were identified to species level by specialists at the Medical Entomology Section. The results of these surveys are summarised below, while the complete technical report is provided in Appendix 21.

Biting midges

Of the biting midges recorded in the trapping surveys, the mangrove biting midge (*Culicoides ornatus*) is the species most likely to be the cause of problems to personnel working in the onshore development area. However, there are other species of biting midges not yet recorded in the trapping program that can be significant pests and are likely to be found in the onshore development area. These include *Culicoides flumineus*, a species normally only found inside mangrove communities and therefore not recorded during the trapping survey (Medical Entomology Section 2009).

The mangrove biting midge will be present in its highest seasonal numbers throughout the onshore development area during the late dry season from August to November. Mass movement of adults can occur from 0.5 to 1.5 km from the mangrove margin of their major breeding sites, with smaller numbers up to 3 km from the nearest mangrove margin. The entire onshore development area is located within 300 to 400 m of mangrove areas, suggesting that *C. ornatus* will be present throughout. Trapping showed a marked peak in numbers on the western edge of Blaydin Point because of the proximity of the upper tidal mangrove tributaries of Lightning Creek. This creek and the small creeks at the south-eastern edge of Blaydin Point contain substantial upper tidal mangrove communities, which will be the most important breeding sites for biting midges affecting the onshore development area (Medical Entomology Section 2009).

Mosquitoes

Mosquito populations at the onshore development area are not expected to be as high as in other parts of Darwin because of the lack of extensive areas of potential breeding sites such as are offered by coastal plains, creeks and rivers. The most productive mosquito breeding sites at Blaydin Point are localised depressions in upper tidal areas, depressions in seepage areas, and the monsoon vine forest near the landward mangrove margin. On Middle Arm Peninsula, borrow pits and depressions in upper tidal areas could provide potential breeding sites for mosquitoes (Medical Entomology Section 2009).

The mosquitoes *Aedes vigilax*, *A. notoscriptus*, *Culex annulirostris*, *C. sitiens* and *Verrallina funerea* were recorded in the onshore development area; these are all pest and potentially disease-carrying mosquito species (Medical Entomology Section 2009).

3.5 Regional climate

3.5.1 Meteorology

Browse Basin

The climate in the Browse Basin region surrounding the Ichthys Field is monsoonal and seasonally controlled by the meridional position of large high-pressure cells, which pass from west to east across the Australian continent (Osborne et al. 2000). These pressure systems, with their anticlockwise wind circulation, migrate from latitudes of 25–30°S in winter to 35–40°S in summer (Pearce et al. 2003). Owing to this pattern, summer (October to February) prevailing winds are warm and come from the north-west and south-west. During winter (May and June), the prevailing winds are cooler south-easterlies.

These winds also result in higher relative humidity in the summer (about 50%) compared with the winter (30–40%). Two shorter transitional periods with more variable wind directions occur between these seasons, usually from March to April and August to September (see Appendix 4).

This area is also prone to tropical cyclones, mostly during the tropical wet season from December to March. It is expected that cyclones could have an impact on the Ichthys Field at least once every two years. Under extreme cyclone conditions winds can reach 300 km/h. The El Niño Southern Oscillation (ENSO) cycle can lead to a lower incidence of cyclones in this region, with cyclones instead forming further east under the influence of El Niño (BOM 2009a).

Darwin

The onshore development area lies in the monsoonal tropics of northern Australia and experiences two distinct seasons—a hot wet season from November to March and a warm dry season from May to September. April and October are transitional months between the wet and dry seasons. Maximum temperatures are defined as hot all year round, but November is the hottest month with a range of 25 °C minimum to 33 °C maximum, while June and July normally experience the lowest average daily temperatures with a range of 20 °C minimum to 30 °C maximum (BOM 2009b). Monthly temperature averages from Darwin International Airport are provided in Figure 3-42.

Darwin has a mean annual rainfall of 1711 mm, with rain falling on an average of 111 days, mainly in the wet season. A range of monthly rainfall averages received at Darwin International Airport (highest, mean and lowest monthly rainfall) is provided in Figure 3-43. Monthly mean evaporation ranges from 167 mm in February to 259 mm in October. The mean annual evaporation rate is 2630 mm (BOM 2009b).

The mean relative humidity experienced at 0900 hours and 1500 hours in Darwin is illustrated in Figure 3-44. The humidity is higher during the wet season than in the dry season, mirroring rainfall patterns.

The wet and dry season wind roses for Darwin are presented in Figure 3-45. As shown, during the wet season Darwin is dominated by westerly and west-north-west winds. Dry-season winds vary from the south-east through to the north.

The monsoonal tropics also experience cyclone activity. The strongest winds and heaviest rainfall are associated with the passage of tropical cyclones, which can occur in the region at any time during the period November to April. Tropical cyclones cause most damage within a distance of 50 km from the coast. Aside from the impacts of strong winds, storm surges can be of concern to coastal developments and flood damage can also result from associated squally rains.

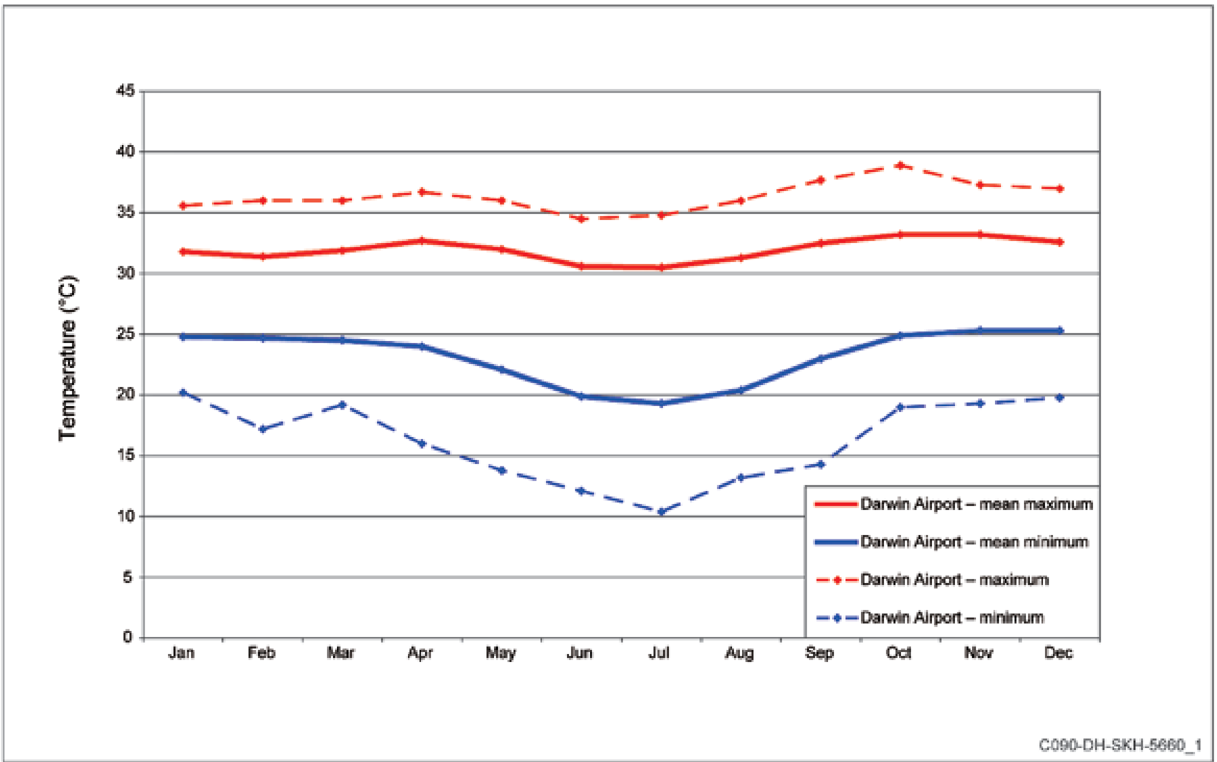


Figure 3-42: Maximum and minimum monthly temperatures for Darwin (°C)

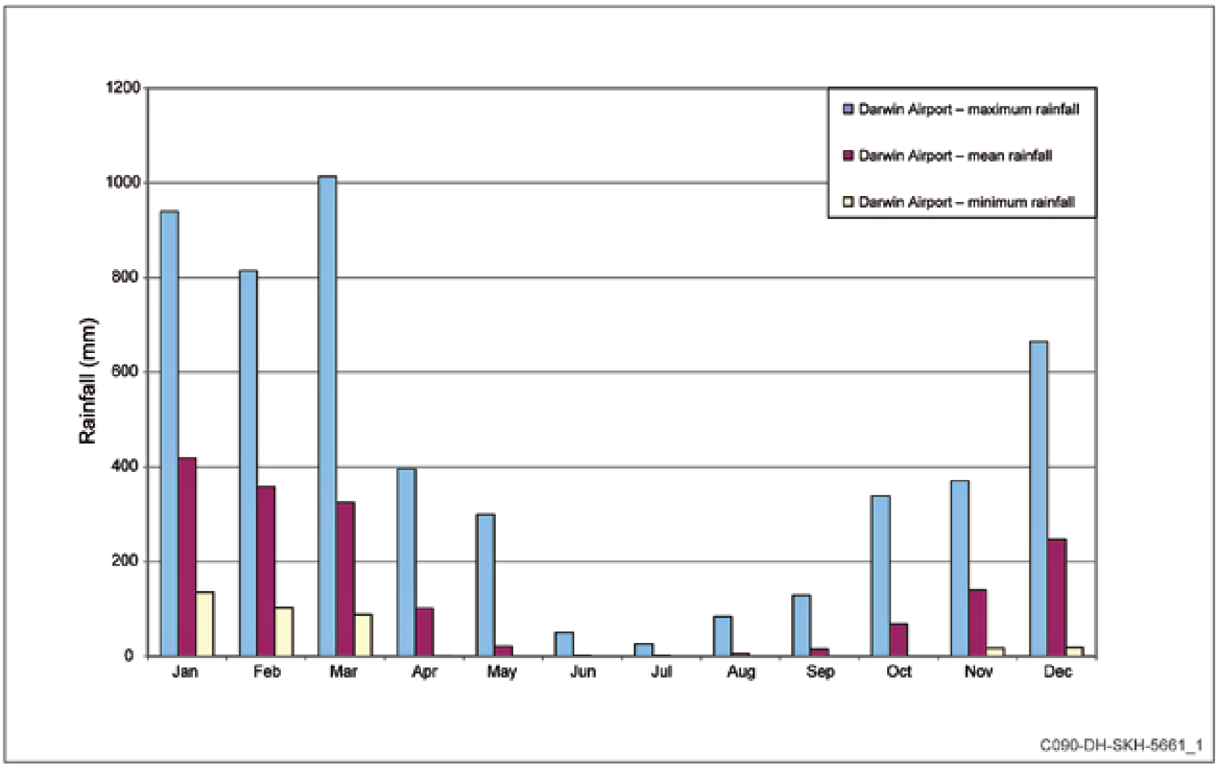


Figure 3-43: Average monthly rainfall for Darwin (mm)

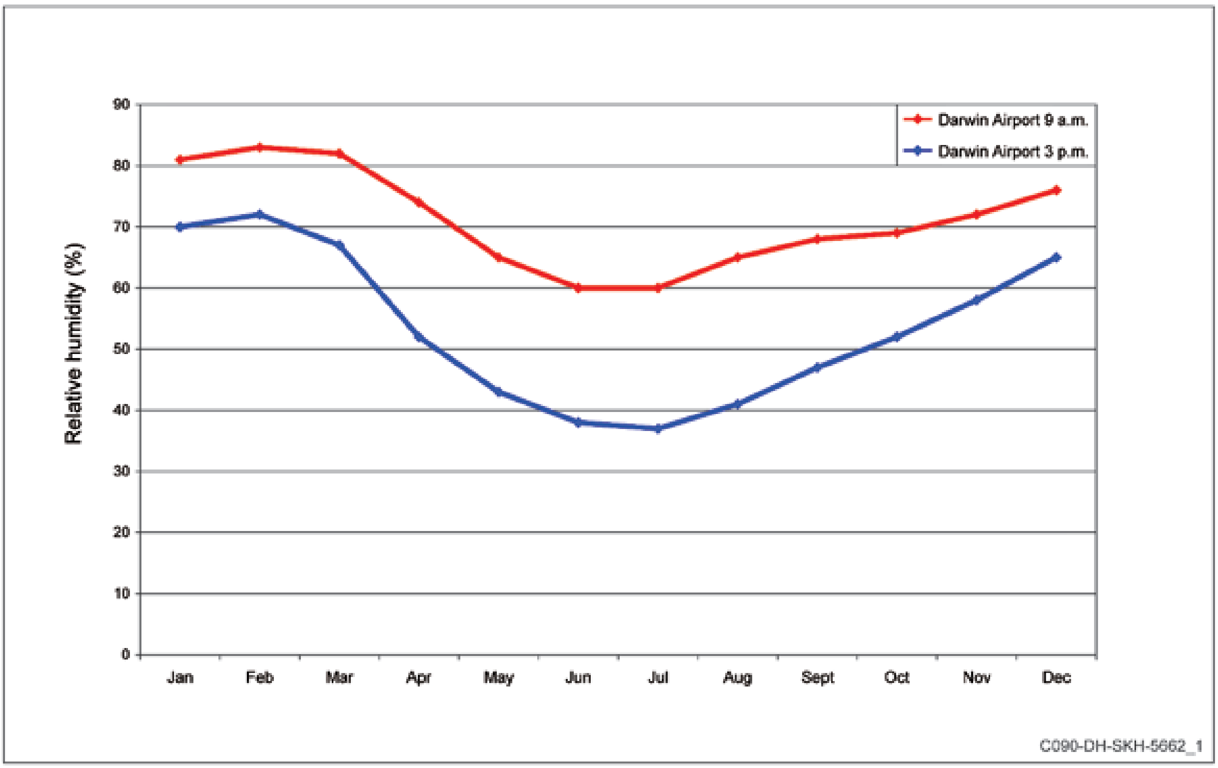
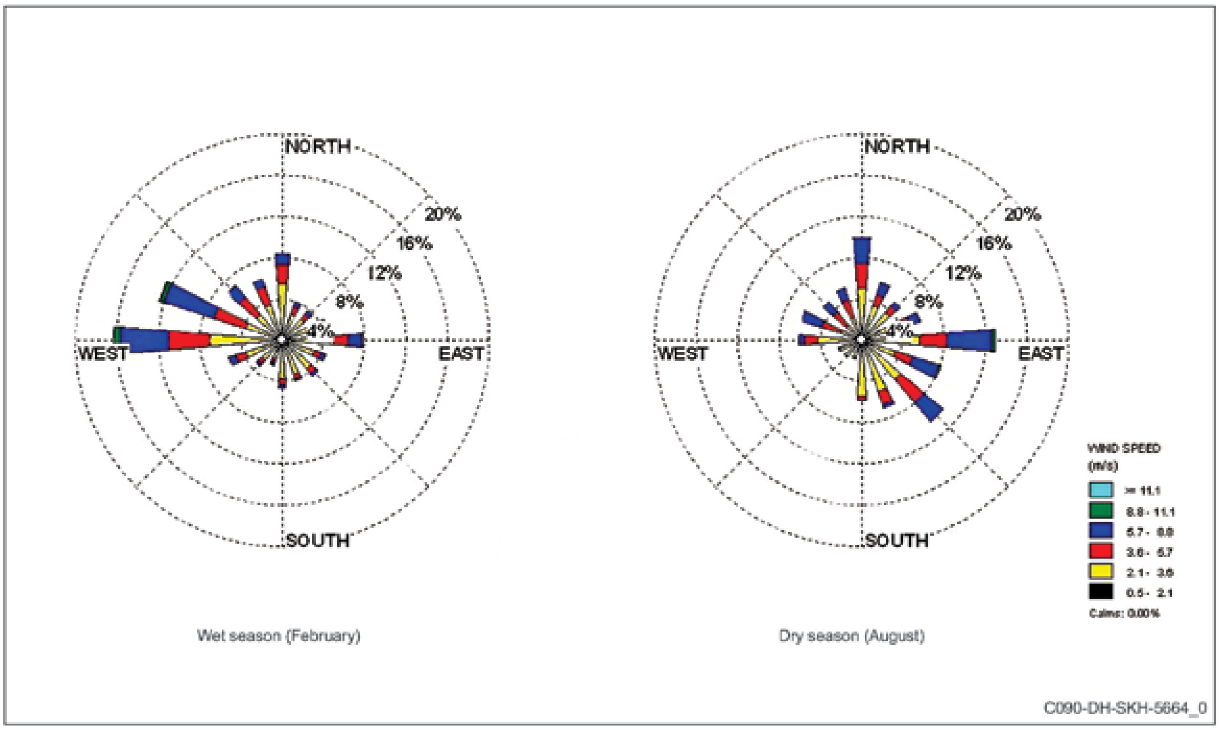


Figure 3-44: Relative humidity for Darwin (%)



Source: SKM 2009.

Figure 3-45: Wind rose for Darwin during wet and dry seasons, 2000–2007

3.5.2 Air quality

Ambient air quality in the Darwin region is influenced by a number of sources including biogenic emissions (from vegetation and soil), smoke from bushfires, and anthropogenic emissions from vehicles and industrial facilities.

Pollutants that could affect public or environmental health, and are relevant in the context of the Project, include particulates less than 10 µm in diameter (PM_{10}), oxides of nitrogen (NO_x, especially nitrogen dioxide NO_2), sulfur dioxide (SO_2), ozone (O_3) and volatile organic compounds (VOCs).

Currently, the major sources of emissions of these compounds in the Darwin region are as follows:

- natural or agricultural vegetation (particularly for VOCs, and particulates during bushfires or prescribed burning)
- soil and bodies of water (particularly for NO_x)
- motor vehicles (particularly for VOCs, NO_x and SO_2)
- ConocoPhillips' Darwin LNG plant
- Channel Island Power Station
- emissions from commercial shipping (SKM 2009).

The National Environment Protection Council (NEPC) provides ambient air-quality criteria as benchmarks for levels of pollutants that could affect public health; these criteria are known as National Environment Protection Measures (NEPMs). Research into the current ambient air quality in the Darwin region was conducted by Sinclair Knight Merz (SKM) in 2008.

A three-dimensional computer-based modelling program (The Air Pollution Model (TAPM), developed by the CSIRO) was used to estimate ambient air quality. Emissions from existing sources in the Darwin region were quantified using publicly available data and the scientific literature. The model accounts for dispersion processes such as convection, sea breezes and terrain-induced flows and it can be used to predict photochemical processes. The results of the ambient air-quality modelling are summarised as follows, with the full technical report (SKM 2009) provided in Appendix 19 to this Draft EIS.

The ambient air quality study found that concentrations of NO_2, SO_2 and O_3 in the Darwin airshed are relatively low, and well below the NEPM criteria as shown in Table 3-15. The highest levels of NO_2 and SO_2 currently occur in the vicinity of the Darwin LNG plant, while the maximum ground-level concentrations of O_3 occur over the ocean approximately 12 km north-west of Darwin (SKM 2009).

Ozone is produced through the photochemical reaction of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). While NO_x emissions can originate from anthropogenic sources (e.g. motor vehicles), VOCs can be emitted in significant amounts by biogenic sources (e.g. tropical vegetation).

Table 3-15: Maximum predicted ground-level concentration on modelled grid

Pollutant	Averaging period	Maximum (ppm)	NEPM criterion (ppm)	Percentage of criterion
NO_2	1 hour	0.03	0.12	23
	Annual	0.002	0.03	8
SO_2	1 hour	0.01	0.20	7
	24 hours	0.006	0.08	7
	Annual	0.002	0.02	10
O_3	1 hour	0.06	0.10	59
	4 hour	0.06	0.08	68

Source: SKM 2009.

However, the emission rates of biogenic VOCs, particularly in Australia, are poorly understood. In addition, few previous measurements of O_3 have been undertaken in the Darwin airshed. In order to increase the accuracy of the VOC input data used in the ambient air quality model, passive sampling programs were conducted by SKM at key sites in the Darwin airshed in the wet season of early 2009 and the dry season later in the year (see Appendix 19).

Estimates of particulate levels in the Darwin airshed were drawn from a pilot study of air quality by the CSIRO in 2000, which suggested that dry-season PM_{10} levels over a 24-hour period were up to 20 µg/m^3, mainly corresponding with smoke generated by bushfires. Wet-season PM_{10} concentrations were lower, at around 10 µg/m^3. The NEPM criterion for PM_{10} is a maximum concentration of 50 µg/m^3 over a 24-hour period, indicating that airborne particulate levels in Darwin are relatively low (SKM 2009).

More recent combined NRETAS and CSIRO air-quality data sets indicate that there were four excursions above the NEPM criterion attributable to smoke from bushfires between 2004 and 2008.

3.6 Social and cultural environment

This section describes the existing social and cultural environment in the Project area, at the local community, territory and national scales.

3.6.1 Description of baseline

A profile of the existing socio-economic conditions in the Project area was developed using publicly available data and published studies. Background socio-economic information relevant to the Project includes a geographical and development context, population demographics, community networks and culture, values and attitudes, and key economic activities.

Data sources and limitations

Baseline study data were collected from government agencies and other sources. The most up-to-date data are used wherever possible; however, for most statistics there is a time lag of several years between collection and publication. This is particularly the case with data relating to composite industries such as tourism (which is made up of the accommodation, transport, recreation, and travel services industries). The basic population data sets used are sourced from the Australian Bureau of Statistics (ABS) *Census of Population and Housing 2006* (ABS 2007a) at the statistical subdivision (SSD) or Territory level unless otherwise stated. As the Census is conducted every five years, the 2006 Census represents the most up-to-date collection of population statistics for the Project area.

Unless otherwise stated, census data are based on location on census night (the place of enumeration). This is the mode most readily available for collecting data as a time series from the 1996, 2001 and 2006 censuses.

The Census rather than the ABS's monthly Labour Force Survey was used in preparing the basic labour force estimates for this study, as data for the Labour Force Survey are collected at an aggregated labour force region level rather than at the SSD level. For the Northern Territory, data are only released for the Territory as a whole. In addition, using the Labour Force Survey does not accurately represent the employment situation in the study area, as members of the Australian Defence Force (ADF) are excluded from participating. Given the large numbers of ADF personnel present in the Northern Territory, this means that employment figures can be an underestimate.

The study area

For the purposes of the socio-economic baseline, the area relevant to the Project has been defined by the statistical divisions (SDs) and statistical subdivisions (SSDs) of the ABS. The Darwin region is represented by the Darwin SD, and comprises the cities of Darwin and Palmerston and the semi-rural Litchfield Municipality. The "Darwin City" and "Palmerston – East Arm" SSDs (Figure 3-46) contain the two major population centres of the region and are the SSDs most likely to be affected by the Project. Therefore population demographics presented in this assessment focus mainly on these two subdivisions.

3.6.2 Government policies and plans

The Project will be regulated through three separate but overlapping levels of government:

- the Commonwealth Government
- the Northern Territory Government
- local government, including Darwin City Council, Palmerston City Council and Litchfield Council.

Direct regulatory control of the Project will be through legislation administered by the Northern Territory and Commonwealth governments. At the policy level, most of the activity occurs at Territory government level and is targeted primarily at the Territory's strategic development plans. Commonwealth policy focuses on broader economic development, although there have been recent developments in relation to marine planning.

There are a number of policies and strategies that are potentially relevant to the Project; these are summarised in Table 3-16.

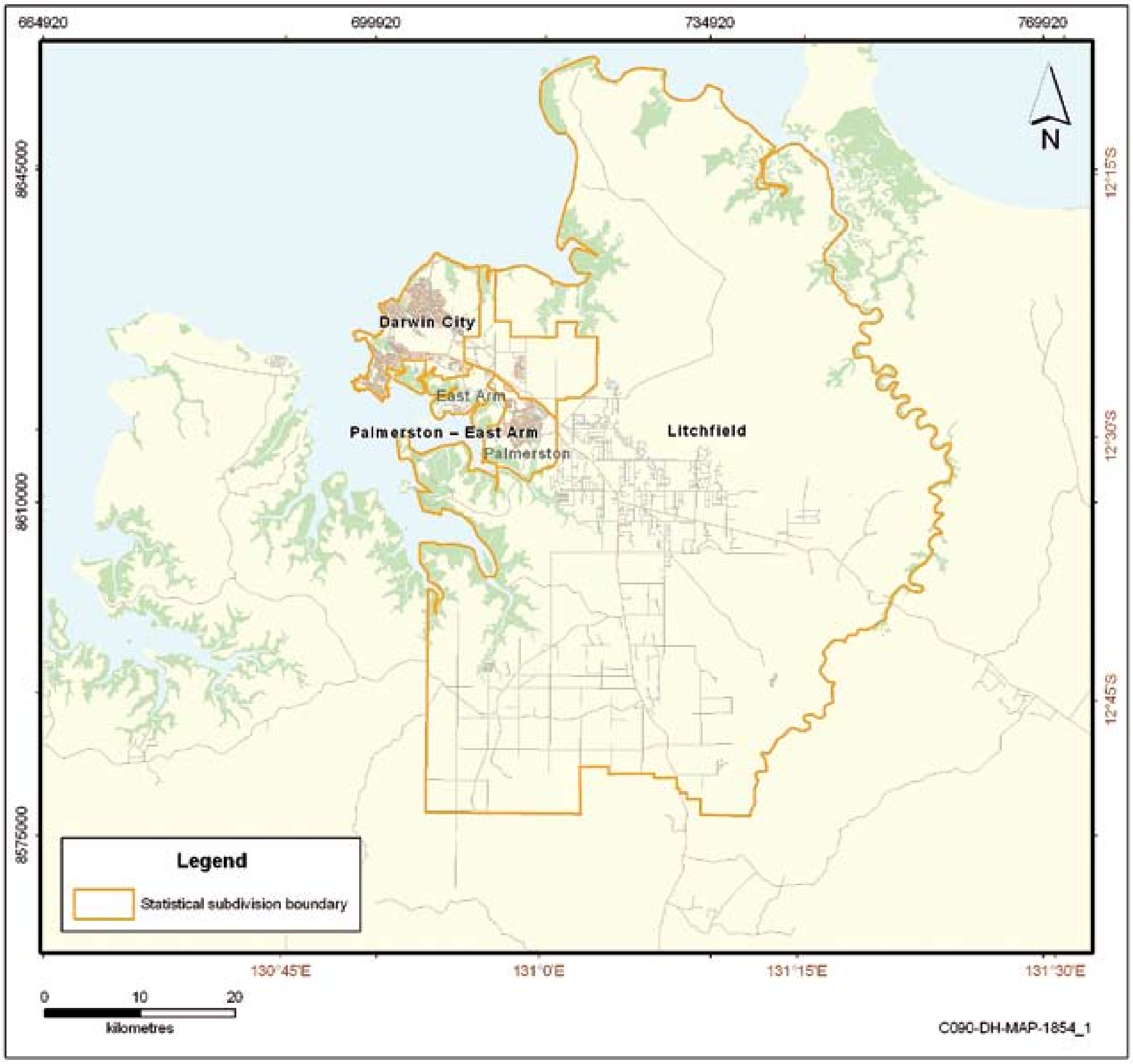


Figure 3-46: Study area statistical subdivisions

Table 3-16: Policies and plans that are potentially relevant to the Ichthys Project

Policies and plans	Description
Commonwealth Government	
Industry statement: global integration—changing markets, new opportunities (Department of Industry, Tourism and Resources, now the Department of Innovation, Industry, Science and Research) (DITR 2007)	This statement delivers three major initiatives to assist Australian firms to succeed as global businesses—"Australian Industry Productivity Centres", the "Global Opportunities program" and changes to the Australian Taxation Office's research & development tax concession.
Marine bioregional planning: a new focus for Australia's marine planning (Department of the Environment and Heritage, now the Department of the Environment, Water, Heritage and the Arts) (DEH 2006b)	This program is intended to assist in assessing the impacts of actions on the Commonwealth marine environment and determining the circumstances under which actions can take place.
Oceans policy: principles and processes (National Oceans Office 2003)	This policy sets out the Commonwealth Government's approach to implementing Australia's oceans policy. It aims to help marine managers and users deliver more sustainable and efficient outcomes. Components include the following: • setting out an approach for implementing Australia's oceans policy • focusing on sustainable outcomes.
Stronger regions, a stronger Australia (Department of Transport and Regional Services, now the Department of Infrastructure, Transport, Regional Development and Local Government) (DOTARS 2001)	The goals of this development framework are to strengthen regional economic and social opportunities; sustain productive natural resources and the environment; deliver better regional services; and adjust to economic, technological and government-induced change. Components include the following: • fostering federal, state and local government cooperation to achieve economic and social objectives for regional communities • improving regional services • helping regional communities to manage change • analysing regional needs and impediments to growth.
Summary of Australia's foreign investment policy (The Treasury 2008)	The foreign-investment policy aims to encourage foreign investment consistent with community interests.
Northern Territory Government	
Building Northern Territory industry participation (Northern Territory Government 2006)	This framework consists of a nationally agreed set of objectives, principles and strategies that will strengthen industry participation and build on existing arrangements. Large projects with expected values of more than $5 million are strongly required (if assisted by the Northern Territory Government) or strongly encouraged (if not assisted by the Northern Territory Government) to develop industry participation plans for engaging local businesses. Components include the following: • increasing local industry participation in projects • supporting sustainable economic development • facilitating education and training opportunities to maximise local jobs • identifying and creating opportunities for Aboriginal economic development.
Economic development framework (Northern Territory Government 2005)	This is a 10-year economic development plan for the Northern Territory. It commenced in 2005 and has five main objectives: encouraging regional growth, promoting investment, developing the local workforce, improving productivity and integrating development with good environmental management. Components include the following: • maintaining a competitive business environment • encouraging greater local content in business and industry • developing workforce skills • using major projects to improve workforce capability • streamlining business regulations.

Table 3-16: Policies and plans that are potentially relevant to the Ichthys Project (continued)

Policies and plans	Description
Palmerston partnership agreement (Northern Territory Government and Palmerston City Council) (Northern Territory Government 2007)	This is an agreement between the Northern Territory Government and the Palmerston City Council to enable cooperative management and planning for the strategic development of the Palmerston area.
Northern Territory planning scheme (Department of Planning and Infrastructure*, Northern Territory Government) (DPI 2008)	This scheme sets out the policy and provisions for the use and development of land throughout the Northern Territory, and provides specific land-zone maps for particular areas. Components include the following: • promoting community, environment and industry through effective land-use planning frameworks • facilitating the supply of land for industry and all other uses so that land subdivision is cost-effective, equitable and maximises the value of public and private investment in infrastructure • contributing to the sustainable use and development of land • valuing land for the ecosystem services it provides.
Darwin Harbour regional plan of management (Northern Territory Government 2003) (NRETAS 2007f)	This plan laid out the goal of protecting the environment of Darwin Harbour through key outcomes such as improving water quality, managing development appropriately, protecting biodiversity, supporting recreational use of the Harbour, and fostering community involvement in Harbour management. Components include the following: • promoting a healthy environment in Darwin Harbour and its catchment • supporting recreational use of the Harbour • encouraging ecologically sustainable development • protecting the cultural values of the Harbour.
Local government	
TOPROC Greater Darwin regional development strategy	TOPROC (Top End Regional Organisation of Councils) is made up of the Darwin, Palmerston, Litchfield, Coomalie, Cox Peninsula and Belyuen local councils. Their collaborative development strategy emphasises key actions such as encouraging appropriate urban development, improving Aboriginal employment levels, and developing a social plan for the area.
Palmerston – a place for people (Palmerston City Council 2007)	Palmerston City Council, supported by the Northern Territory Government, developed this community plan for the future development of Palmerston in 2003. In 2007 the council adopted the Palmerston City Plan for 2007/08 – 2009/10 as the implementation strategy for the plan. It provides for Palmerston's development in a socially, environmentally and economically sustainable manner. Components include the following: • increasing job readiness through partnership with industry and training providers, with particular emphasis on youth and Aboriginal employment • encouraging major projects that meet environmental and social sustainability objectives • promoting Palmerston as a regional supply and service centre.
Evolving Darwin: strategic directions—towards 2020 and beyond (Darwin City Council 2008)	In 2008 Darwin City Council released a discussion paper outlining future directions for Darwin City. These directions will be built around issues of improving lifestyles, connectivity, governance, environmental sustainability and a cohesive community. Components include the following: • developing collaborative relationships with all stakeholders • improving the active, positive lifestyle enjoyed by Darwin residents • maintaining environmental sustainability • facilitating the development of a cohesive community.

* The Department of Planning and Infrastructure became the Department of Lands and Planning in December 2009.

3.6.3 Land tenure and sea use

Middle Arm Peninsula was identified as a site for future industrial development by the Northern Territory Government and is classified as such under the Northern Territory Planning Scheme (DPI 2008). The onshore development area on Middle Arm Peninsula is currently undeveloped vacant Crown land falling within the jurisdiction of the Litchfield Council. Previous sites of disturbance in the area include around 25 ha of borrow pits, and a number of access tracks left by previous development projects.

Current use of the land and marine environment on Middle Arm Peninsula includes a power station on Channel Island and ConocoPhillips' Darwin LNG plant and offloading facility at Wickham Point. A number of aquaculture ventures also exist around the peninsula, and the area is regularly used for recreational fishing. Lightning Creek, west of Blaydin Point, currently contains a pearling lease and is utilised as a cyclone mooring for vessels—whether these facilities will remain in future years is unknown. Blaydin Point itself is accessible by four-wheel-drive vehicles using informal tracks and there is also evidence of camping.

In Darwin Harbour, the most intensive use of the marine area is for commercial shipping, recreational boating and military activities. Underwater power and communication cables extend across the Harbour on the seafloor between Mandorah and Myilly Point, and the Bayu–Undan Gas Pipeline to the Darwin LNG plant runs down the middle of the Harbour.

The Charles Darwin National Park is located in Frances Bay between the Darwin CBD and East Arm Wharf. Marine areas in this park include the western bank of Sadgroves Creek, Reichardt Creek and part of Blessers Creek, and a large portion of intertidal mudflat. Other conservation areas in the Harbour include the Channel Island Reef, which contains a coral community and is a listed heritage place on the Register of the National Estate (see Section 3.3.6 *Marine communities*). Fisheries management areas have been designated at Doctor's Gully Aquatic Life Reserve (near Darwin's CBD) and at the East Point Aquatic Life Reserve (near the mouth of Darwin Harbour), to reduce commercial and recreational fishing activity, under the *Fisheries Act* (NT).

Tourism activities such as charter fishing, scuba-diving, sailing and general boating are undertaken throughout the Harbour. Very little commercial fishing is undertaken in the Harbour; the commercial fisheries in the nearshore and offshore development area are described in detail in Section 3.7.4 *Commercial fishing and aquaculture*.

Aboriginal people living in the Darwin area frequently fish and forage for food and other resources in intertidal areas at low tide. These activities are common in the Harbour around Nightcliff, Coconut Grove, Kululuk, Sadgroves Creek and Lee Point. There are currently seven Aboriginal fisheries consultative committees in the Northern Territory. The Beagle Gulf Fisheries Committee was formally established in April 1999 and covers the Darwin Harbour region. Key issues discussed at these meetings include the involvement of Aboriginal people in the enforcement of fisheries regulations and the wasted bycatch from commercial barramundi fishers.

The Royal Australian Navy's Northern Australia Exercise Area (NAXA) extends west of Darwin into the Bonaparte Gulf. This marine area is used to conduct realistic at-sea exercises with naval and shore-based weapon-firing training (RAN 2006).

3.6.4 Demographics and population trends

The ABS population statistics in this section are based on place of usual residence. This means that the people counted actually live in the locality presented for at least six months of the year. The data were collected by the five-yearly ABS *Census of Population and Housing*, conducted in 1996, 2001 and 2006.

Population

The population of the Northern Territory in 2006 was 192 898 people, representing approximately 1% of Australia's total population. Around half of this population resided in the Darwin region. Population statistics for Darwin City, Palmerston – East Arm and the Northern Territory are presented in Table 3-17.

The Darwin regional population grew by 5.7% between 2001 and 2006, which is comparable to the increase in Australia's population over the same period (5.8%). Much of this growth was concentrated in the Palmerston – East Arm locality, where the rate of growth was 13.9% (ABS 2002, 2007a).

Table 3-17: Population statistics for the Darwin region, 2001 and 2006

Locality	2001	2006	Percentage change
Darwin City	64 341	66 290	+3.0
Palmerston – East Arm	21 192	24 145	+13.9
Darwin region	100 255	105 990	+5.7
Northern Territory	188 075	192 898	+2.6

Sources: ABS 2002, 2007a.

In 2006, Aboriginal people made up approximately 28% of the Northern Territory population, compared with 2.3% nationally. Most (83%) lived outside the Darwin region. Although relatively small, the Darwin regional population of Aboriginal people increased significantly (by 12%, or around 1000 people) from 2001 to 2006. This is comparable to the growth rate of the national Aboriginal population (ABS 2002, 2007a).

Population projections

Based on 2004 population estimates, by 2021 the Northern Territory's population is expected to grow to between 215 300 and 279 200 people. The greater part of this growth is likely to occur in the Darwin region. Upper growth rates estimate that Darwin's population will increase by 51%, showing a rate of increase nearly double that of Australia as a whole (24%) (ABS 2008a). Population projections for the Darwin region in 2021 and 2051 are provided in Table 3-18.

Ethnic diversity

Perhaps because of its geographical proximity to South-East Asia, Darwin is relatively ethnically diverse. ABS statistics indicate that 34% of the Northern Territory population speak a language other than English at home, including Aboriginal languages, Chinese, Greek and Indonesian. The 2006 Census shows that 30.6% of Darwin's population was born overseas, an increase from 28.6% in 1996 (ABS 2007a).

Age and sex ratio

The age structure of Darwin's population is much younger than that of the general Australian population (Figure 3-47), mainly because of the high turnover of the working-age population and the younger age structure of the Aboriginal segment of the population. There is a particularly high proportion of adults in the age 25–34 and age 35–44 categories in the Darwin region, and much lower proportions of senior and elderly people (age 55 and over) than the Australian averages. The median age of both males and females in the Northern Territory is 30 years, compared with the national median ages of 35 and 37 years for males and females respectively.

On the community level, there are proportionally more children (0–14 years old) and young adults (25–44) in the Palmerston – East Arm area than in Darwin City. The proportion of older people (age 45 and over) in the population is much higher in Darwin City (ABS 2007a).

There are generally more men than women throughout the Northern Territory, unlike the rest of Australia where women are slightly more numerous. In Darwin City, there are 106.6 males per 100 females, while there are 104.4 males per 100 females in Palmerston – East Arm (ABS 2007a).

Family structure

As suggested by the population age structures, there are more young families living in Palmerston – East Arm than in Darwin City, and both communities have more young families than the general Australian population. Some 56% of families in Palmerston – East Arm have children under 15 years old, compared with 43% for Darwin City and 40% for the whole of Australia.

3.6.5 Income support payments

A relatively small proportion of residents in Darwin City and Palmerston – East Arm receive income support from the government: 16% and 14% respectively, compared with the national average of approximately 23%. The proportion receiving the age pension is much lower, as would be expected considering the younger age structure in the Darwin region and Northern Territory.

The Newstart Allowance, which is available to those seeking employment, is received by a high number of people in the Northern Territory: 7.2% compared with 2.8% nationally. However, Newstart Allowance is only claimed by 3.8% of people in Darwin City and by

Table 3-18: Population estimates for the Darwin region for 2021 and 2051

	2004	2021		2051	
	Current population (thousands)	Lower growth estimate (thousands)	Upper growth estimate (thousands)	Lower growth estimate (thousands)	Upper growth estimate (thousands)
Darwin region	109.4	127.5 (16.5%)	164.8 (50.6%)	153 (39.9%)	295.5 (170.1%)
Northern Territory	199.8	215.3 (7.8%)	279.2 (39.7%)	224.3 (12.3%)	470.5 (135.5%)
Australia	20 091.5	22 988.4 (14.4%)	24 878.4 (23.8%)	24 864.5 (23.8%)	33 389.8 (66.2%)

Source: ABS 2008a.

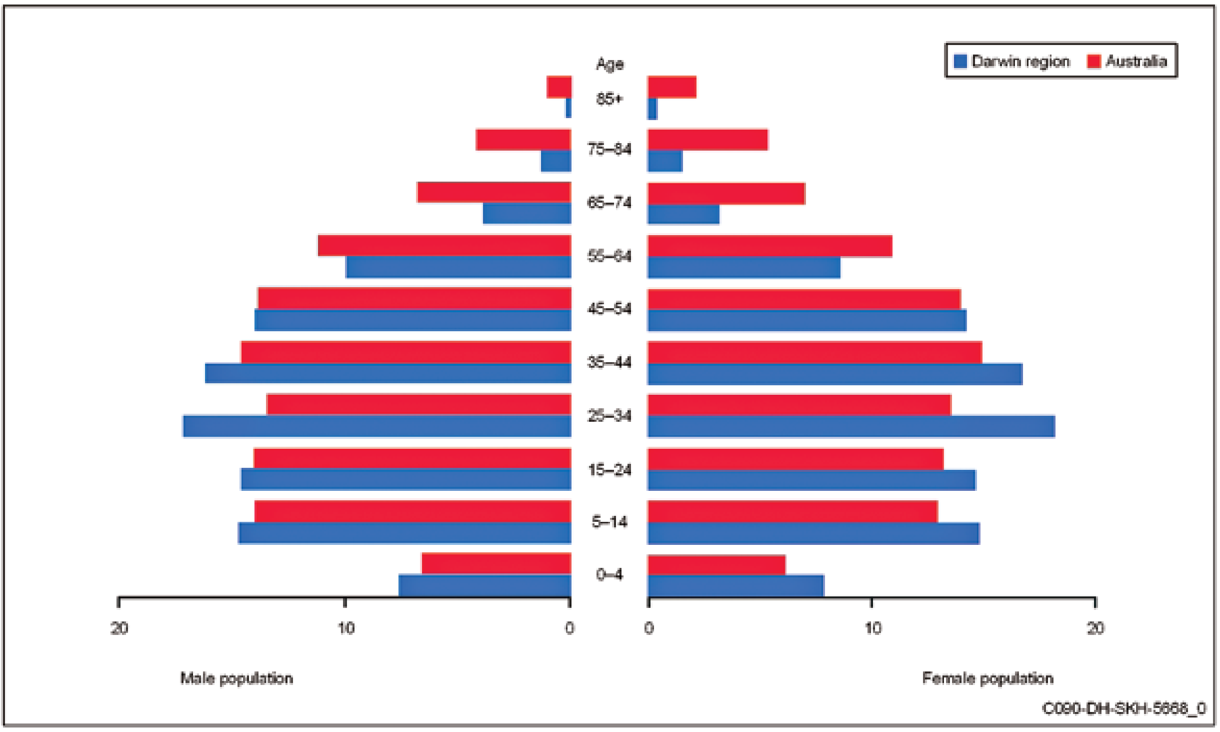


Figure 3-47: Population distribution by age in the Darwin region and Australia in 2006

2.8% in Palmerston – East Arm. This apparent high unemployment level is therefore likely to be affecting people in more remote areas of the Northern Territory.

3.6.6 Education and training profile

The Darwin City population shows a level of schooling similar to that of the overall Australian population, with 44% of people having completed Year 12 compared with the national average of 42%. Far fewer have completed senior school in Palmerston – East Arm (33%). The Northern Territory average is also low (33%) (ABS 2008b).

The Charles Darwin University (CDU) was formed in 2003 by a merger of the Northern Territory University, the Alice Springs-based Centralian College, the Northern Territory Rural College in Katherine, and the Menzies School of Health Research. The Menzies School of Health Research is a joint venture between the CDU, the Menzies Foundation and the University of Sydney and is located at the Royal Darwin Hospital, close to the university.

The CDU is a "dual-sector" university, which means that it offers courses from vocational education and training (VET) through to higher education undergraduate and postgraduate courses over a wide range of subjects and disciplines. There are campuses in both Casuarina and Palmerston, and courses are offered in business, the arts, education, health, science and technology.

3.6.7 Training

One of the aims of the Northern Territory's Department of Education and Training (DET)[7] is to build and expand the skills of the Northern Territory workforce, and it works with industry to improve the access of Territorians to the opportunities arising out of a growing economy. The DET provides a choice of over 390 industry apprenticeships and traineeships in the Territory and aims to achieve 10 000 apprentice and trainee commencements over four years. The Northern Territory's Employer Incentive Scheme, included in a range of strategies in the Northern Territory's Jobs Plan, provides eligible Territory employers with financial incentives aimed at promoting the uptake of additional apprentices and trainees.

The Department's 2007–2008 annual report highlights an increased uptake and completion of apprenticeships and traineeships following the implementation of a range of strategies to increase commencements, completions, and retention rates of apprentices and trainees. The number of apprentices and trainees in training increased from 2500 in 2002–03 to 3300 in 2007–08, with at least 2800 new commencements in 2007–08. A total of 317 Occupational Shortage Employer Incentives, valued at $4000 each, was allocated in 2007–08 to encourage employers to take on an apprentice in areas of occupational shortage (DEET 2008).

7 The Department of Employment, Education and Training became the Department of Education and Training in August 2008.

Training for Aboriginal and Torres Strait Islander people

The DET provides funding for training programs for Aboriginal and Torres Strait Islander people and provides opportunities for them to access VET. The programs include the following:

- The "flexible response funding" program, which delivers short training programs on site in the community, with content tailored to community projects or local enterprise development (DET 2009a)
- The "training for remote youth" program, which is aimed at bringing together youth that are disengaged from school and training organisations, to prepare them for employment in the community or re-engage them in further learning (DET 2009b)
- The "Indigenous training for employment program", which supports practical projects that ensure that adults in regional and remote areas can take up VET (DBE 2009).

The Indigenous Economic Development Taskforce, whose membership is drawn from national and Northern Territory Indigenous organisations, from industry, and from Northern Territory and Commonwealth government agencies, identifies opportunities for Aboriginal and Torres Strait Islander economic development in Northern Territory communities in 13 targeted industry sectors (Northern Territory Government undated).

3.6.8 Housing

Household size and status

The average household sizes in Darwin City and Palmerston – East Arm are 2.6 and 2.7 respectively for family and non-family households; this is very similar to the national average household size (ABS 2007a).

In 2006, most of the housing in Palmerston – East Arm consisted of separate dwellings (76.5%, compared with 12.3% semi-detached, terrace or townhouses and 10.1% units) (ABS 2007a). Townhouses and units are much more common in Darwin City, where a large number of high-rise residential apartment buildings have been constructed in recent years.

Housing availability

Demand for inner-city housing in Darwin has been continually increasing, driven by the migration of new workers in the mining, tourism and defence industries from interstate and overseas (Propell National Valuers 2008). Population growth as well as strong wages growth have caused house and rent prices to continue rising. In the June quarter of 2008 house prices grew at 3.51%, the highest rate in the country.

Demand for rental properties is extremely high, with rental vacancy rates at 1.3%. Median rents in inner Darwin increased by 14.2% to $480 per week for a three-bedroom house over the year to June 2008. Demand for rental properties in Palmerston is also high, with the median rent increasing by 18.3% to $360 over the same period (Propell National Valuers 2008).

Future housing developments

In 2008, it was noted that the Northern Territory's Department of Planning and Infrastructure (DPI)[8] was releasing approximately 300 new lots of land in the Darwin region every year and that this number might increase significantly in response to future population growth (Calacouras 2008).

New suburbs planned for development in the City of Palmerston from 2009 include Johnston, Mitchell, Bellamack and Zuccoli (Calacouras 2008; Northern Territory Lands Group 2009). The Berrimah Farm subdivision, located between Palmerston and Darwin was also intended to provide new lots of land for residential development (Northern Territory Government 2008a) but is currently being reconsidered along with other areas (Calacouras 2009).

3.6.9 Road traffic

Darwin and Palmerston

To characterise the existing traffic conditions and volumes on major roads in Darwin and Palmerston, and on Middle Arm Peninsula, URS conducted a traffic assessment in September 2008. Information on traffic volumes and vehicles was provided by the DPI, and data on turning movements at major intersections were collected through live traffic surveys conducted by Territory Asset Management Services. The main results of the study are summarised below, while the complete technical report (URS 2009f) is provided in Appendix 22 to this Draft EIS.

The road networks through the cities of Darwin and Palmerston are broadly structured around the Stuart Highway, a dual carriageway that runs approximately east–west. Tiger Brennan Drive is a major road which runs parallel to the Stuart Highway between Darwin and the suburb of Berrimah and then links with Wishart Road to continue as an alternative route to Palmerston. A number of north–south arterial roads connect Stuart Highway and Tiger Brennan Drive and then extend further into the suburban areas of Darwin and Palmerston (URS 2009f).

8 The Department of Planning and Infrastructure became the Department of Lands and Planning in December 2009.

Along the Stuart Highway, traffic volumes are heaviest near the Darwin CBD, with an average of 26 591 vehicles per day in 2007. Traffic volumes on the Stuart Highway decrease to around 17 000 vehicles per day in the vicinity of Palmerston. Speed limits vary on the highway between 60 km/h and 100 km/h (URS 2009f).

The city of Palmerston is based on a network of curvilinear collector and local roads, with intersections with Stuart Highway to the east. Chung Wah Terrace is the main collector road running through Palmerston. It connects to Channel Island Road and is a single carriageway with very few private access driveways and speed limits of 60–80 km/h. Average traffic volumes on the main collector roads in Palmerston were around 5000–7000 vehicles per day in 2007 (URS 2009f).

Berrimah Road provides a key link between East Arm Wharf and the Stuart Highway and also intersects Tiger Brennan Drive and Wishart Road. It is a single carriageway with speed limits of 60–80 km/h. The road condition is poor in some parts, although Berrimah Road is currently undergoing major redevelopment. A relatively high proportion of commercial vehicles (28%) utilise this road at its southern end near East Arm Wharf (URS 2009f).

Channel Island Road is the main access road along Middle Arm Peninsula and is a rural single-carriageway road with speed limits of 80–100 km/h. It links with Wickham Point Road, which provides access to Blaydin Point and the Project's onshore development area. Channel Island Road is connected to Palmerston by the single-carriageway Elizabeth River Bridge (URS 2009f).

Quarry traffic

Sources of hard rock (e.g. for rock armouring) in the region include quarries at Mount Bundy, 100 km east of Darwin along the Arnhem Highway, and Katherine, 300 km south of Darwin on the Stuart Highway.

The Arnhem Highway is a Northern Territory arterial road which connects Darwin to Kakadu National Park. The route from Darwin to Mount Bundy passes through freehold land, Djukbinj National Park and Defence land (Mount Bundy Training Area), as well as the towns of Corroboree Park and Humpty Doo. The Arnhem Highway carries mainly light-vehicle traffic from locals, tourists and Defence personnel. Heavy-vehicle traffic includes freight trucks and vehicles servicing the Ranger Uranium Mine near Jabiru. The highway is subject to flooding at some points during the wet season and can be closed for a few days at a time.

The Stuart Highway is a National Highway. The route from Katherine to Darwin passes through freehold land, towns (Pine Creek, Hayes Creek, Adelaide River, Acacia and Noonamah), the Manton Dam Recreation Area, and the Aboriginal lands of Jawoyn, Barnjarn, Wagiman and Larrakia. The Stuart Highway carries heavy commercial vehicles (e.g. road trains), light commercial vehicles (e.g. courier vans), tourist vehicles (e.g. coaches and caravans), and local light-vehicle traffic. It is a high-use road, especially in the dry season, as it connects Darwin to other major cities and regional centres.

From Humpty Doo into Darwin, both quarry routes use the Stuart Highway, through rural-residential land to the outskirts of Palmerston, and through medium commercial and residential areas from Palmerston through to Berrimah Road. The route to East Arm Wharf passes a school (Kormilda College), many commercial premises and the Darwin Railway Station. The route to Blaydin Point passes through some residential areas in Palmerston (via Lambrick Avenue and Chung Wah Terrace) and leads on to Channel Island Road, which carries mainly commercial traffic to the Channel Island Power Station, aquaculture areas and the Darwin LNG plant.

3.6.10 Maritime traffic

The Port of Darwin contains well-established trading and recreational facilities that receive a wide variety of vessels ranging from small pleasure boats to commercial tankers. The port boundaries encompass all parts of Darwin Harbour (including East Arm, Middle Arm and West Arm) and extend into Beagle Gulf. Facilities and trade at the Port of Darwin are described in more detail in Section 3.7.5 *Industrial infrastructure and services*.

Vessel traffic in the port has been increasing since 2004, as shown in Figure 3-48. Most maritime traffic is made up of non-trading vessels such as naval vessels, research and recreational craft, fishing and fishing supply vessels, and pearling industry support vessels. Trading vessels are commercial ships carrying cargo or passengers, and include rig tenders, tankers, livestock carriers, bulk-cargo vessels, barges and cruise vessels (Darwin Port Corporation 2009).

In 2008–09, the main types of non-trading vessels utilising the port were fishing and prawning boats (92%) followed by other small vessels such as patrol boats (3.6%). Trading vessels mainly consisted of barges and stone-dumping vessels (36%) and rig tenders (32%), while bulk-liquid tankers (e.g. petroleum tankers) represented 7% of all vessels (Darwin Port Corporation 2009).

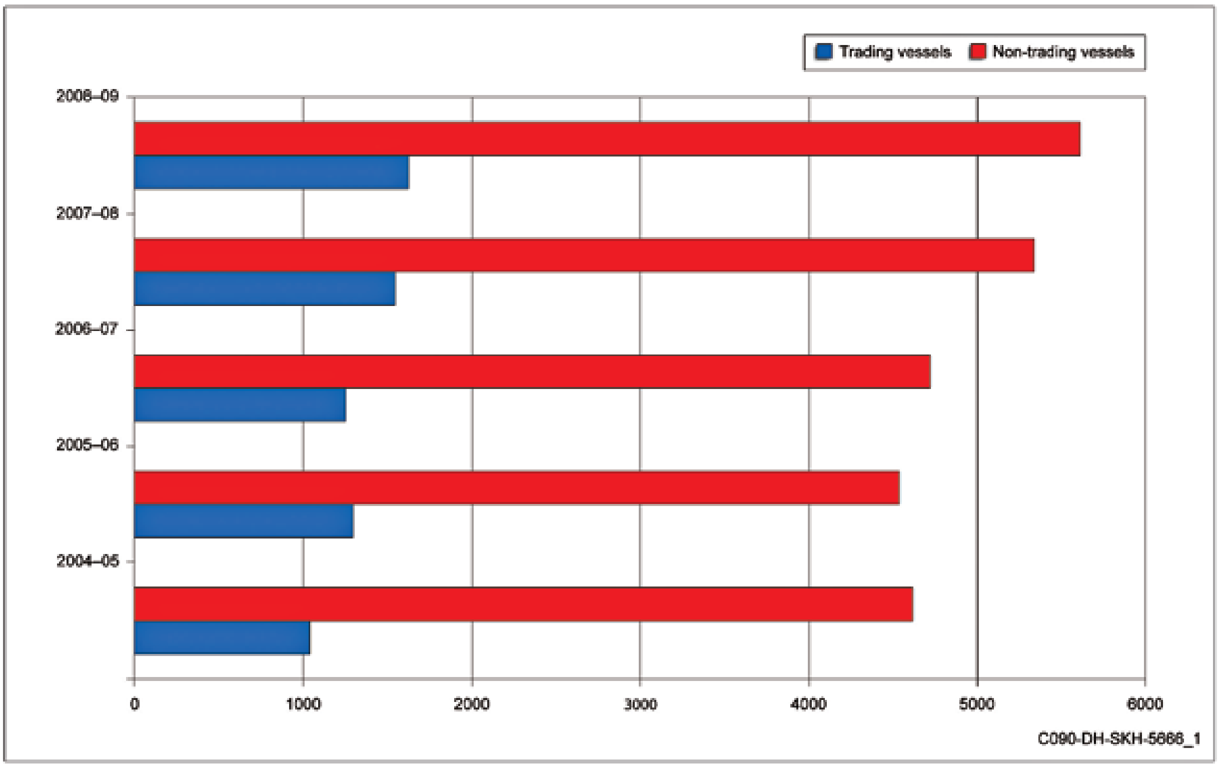
3.6.11 Social infrastructure and services

The major community facilities and services available in Darwin and Palmerston are as follows:

- two hospitals—the Royal Darwin Hospital (350 beds) and Darwin Private Hospital (87 beds)
- specialist health services including mental health programs, aged and disability programs, alcohol and other drug programs, oral health services, audiology and hearing health services, women's health programs, cancer screening, child protection and family support programs
- two privately run nursing homes and a palliative-care centre
- a mixture of 37 government- and privately operated childcare centres, which had 3631 places in 2006–07 (DHCS 2007)
- four police stations and four fire stations, serviced by the Joint Emergency Services Communications Centre
- sewage treatment and disposal services, administered by the Power and Water Corporation
- land-based transport infrastructure including the Stuart Highway and AustralAsia Railway
- shipping transport infrastructure at Darwin
- airport infrastructure at the Darwin International Airport, out of which several airlines operate (including Qantas, Jetstar, Garuda, Airnorth, Virgin Blue and Skywest)
- public bus transport services, including special services for schools, people with disabilities and the elderly
- entertainment and cultural facilities including the Darwin Entertainment Centre, Darwin Convention Centre, Northern Territory Museum and Art Gallery and the Darwin Botanic Gardens
- sports and racing facilities including the Marrara Sports Complex, TIO Stadium, Darwin Turf Club and the Hidden Valley Motorsports Complex
- telecommunications services including landline, mobile phone and satellite phone services, and broadband internet. Service providers include Telstra, Optus and Vodafone
- a number of television networks, including ABC, SBS, Channel Nine, Southern Cross Television (SCTV—formerly Channel Seven), and AUSTAR pay television
- a number of radio stations, including ABC, commercial and community-based stations.

3.6.12 Recreation

Lifestyles in the Northern Territory are often described as "laid-back" or "relaxed", and are characterised by outdoor-based activities. Popular recreational activities in the Darwin region include fishing, sailing, waterskiing, swimming, camping and off-road driving.



Source: Darwin Port Corporation 2009.

Figure 3-48: Annual number of vessels visiting the Port of Darwin

Darwin Harbour is a prime recreational and tourism resource for the region. The qualities and resources of the Harbour make it an aesthetically beautiful place with high recreation values. Fishing, boating, scuba-diving, sailing, waterskiing and beach use are popular activities. A 1997 survey on Darwin Harbour visitation found that 50% of respondents (out of 700) visited the Harbour once a week or more (Brown & Reynolds 1997).

The Northern Territory has the highest rate of fishing-club membership in Australia. The National Recreational Fishing Survey conducted in 2000 suggested that over of 540 000 hours were spent fishing in the Darwin region during the survey year, half of these by Darwin residents and half by visitors to the region. Around one-third of all fishing effort occurs in Darwin Harbour (Coleman 2004). The amount spent by tourists and locals on recreational fishing in the Northern Territory is estimated to be nearly $35 million per year. This does not include the many fishing-tour operators, most of whom operate out of Darwin. Because of the risks from saltwater crocodiles and tidal surges, most fishing is conducted by boat.

Species commonly fished in Darwin Harbour include snapper, mud crab and small baitfish, as well as barramundi and some game fish. There are four marinas for private boats in Darwin Harbour: these are Cullen Bay Marina, Tipperary Waters Marina, Bayview Marina and the Frances Bay Mooring Basin.

3.6.13 Aboriginal cultural heritage

Archaeology

Archaeological surveys were undertaken throughout Middle Arm Peninsula by Earth Sea Heritage Surveys in October 2007 (Bourke & Guse 2007). The majority of the archaeological sites and objects recorded in the area are associated with past Aboriginal use of marine resources and are located within 300 m of the shoreline.

Middle Arm Peninsula is within the traditional country of the Larrakia people. Subsistence activity for this group of Aboriginal people was concentrated in areas close to sources of water and raw materials suitable for stone artefact manufacture, such as creeks, waterholes, ridges and hills. The meeting points between tidal areas or the mangrove zone and the adjacent higher ground regularly yield archaeological artefacts from Aboriginal activities.

There are approximately 117 previously recorded archaeological sites located on Middle Arm Peninsula west of the Elizabeth River Bridge (Bourke 2005; Bourke & Guse 2007; Crassweller 2006).

The majority contain shells of the mollusc *Anadara granosa* either as a midden (mound of debris) or a scatter. The gastropod *Telescopium telescopium* is often the dominant shell present in the shell scatters. Around one-third of the sites also have stone artefacts present on the surface. Eight sites and one isolated artefact are located close to, or within, the boundary of the onshore development area (Figure 3-49).

Places of cross-cultural engagement are generally referred to by archaeologists as “contact period” sites. Very few of these types of sites have been documented for the Darwin region, and two have been recorded on Middle Arm Peninsula. One of these is located close to the proposed access road to Blaydin Point (labelled “Shell and glass scatter” in Figure 3-49), and contains dark green bottle glass that has been modified for use by Aboriginal people. Research at this site could provide information on continuity and change in Aboriginal occupation in the region over many hundreds of years, and on the incorporation of new technological products, such as European glass, into existing Aboriginal systems (Bourke & Guse 2007).

There are no archaeological or historical sites recorded on either the Register of the National Estate or the National Heritage List located in the vicinity of the onshore development area, nor any heritage places and objects recorded on the Northern Territory Heritage Register.

Sacred sites

The Aboriginal Areas Protection Authority (AAPA) identified six sacred sites in the vicinity of the nearshore development area (Figure 3-50). Sacred sites are surrounded by “restricted works” areas in which, under the provisions of the *Northern Territory Aboriginal Sacred Sites Act* (NT), no land or maritime development works of any kind are allowed.

One of the identified sacred sites is located approximately 2.4 km north-west of Blaydin Point in the waters of Darwin Harbour (Figure 3-50). This site is known as “Yirra” and features in a Dreamtime story about the Kangaroo. Yirra was described as part of the EIS developed by the Phillips Oil Company Australia for the Darwin LNG plant (Dames & Moore 1998), as follows:

> This story involves the Dreaming Kangaroo, who was travelling north fleeing people who did not speak his language. As the Kangaroo travelled northwards he hopped across from the land south of what is now known as Middle Arm, landing on the dry land on Wickham Point. By this stage the Kangaroo was exhausted from being chased for so long but knew he had to get to the East Arm side of the mainland to be safe. His only choice was to jump to the other side, and in doing so he realised he would never make it. Just as he was going to go down into the water, Yirra Island came up for him to rest his foot on.

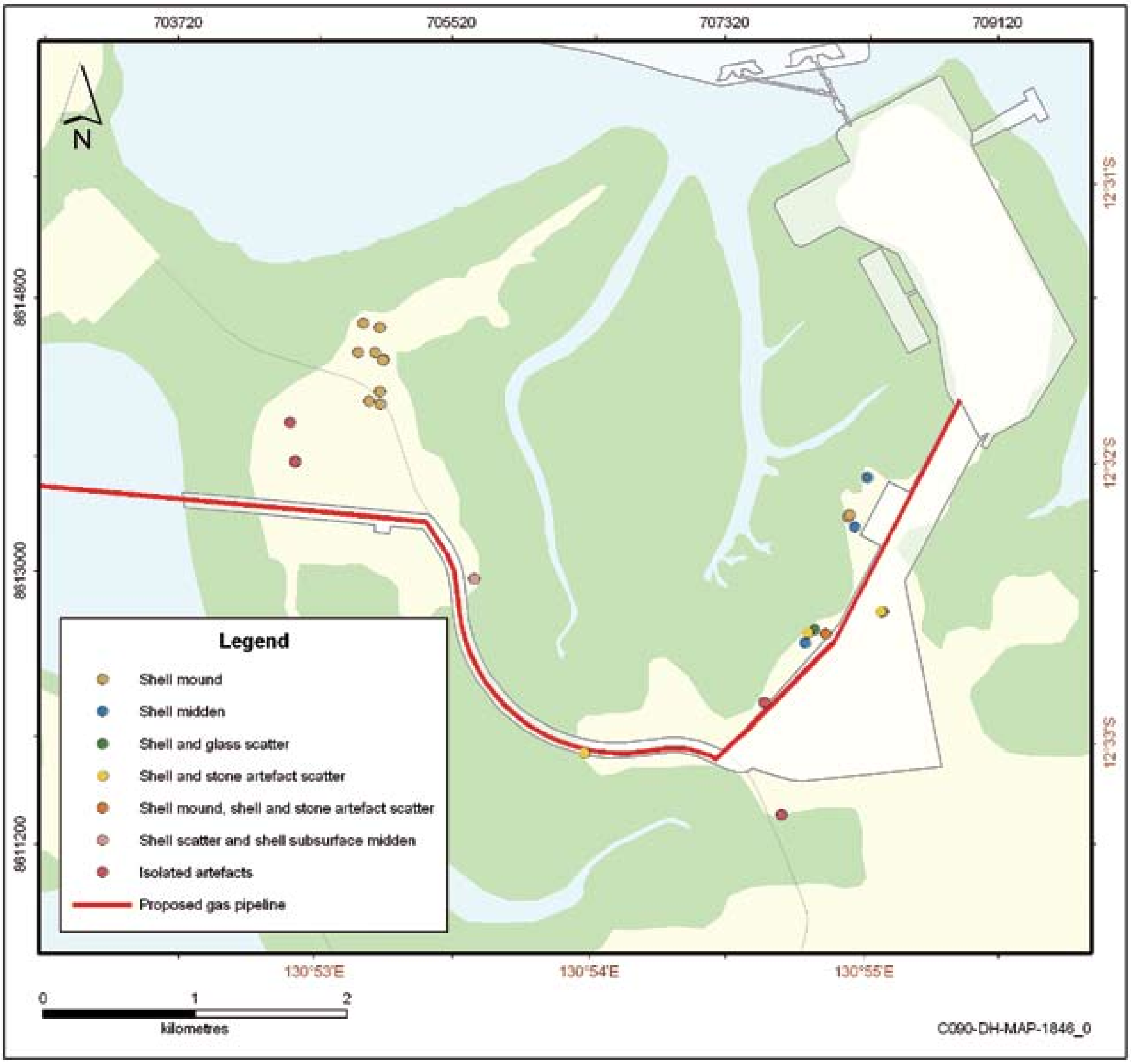


Figure 3-49: Aboriginal heritage sites in the vicinity of the onshore development area

The area of water around the island is believed to be dangerous; people approaching should do so in a certain way so that the Kangaroo does not thrash its tail and swamp their boats. The sand bars extending from the island represent the tail of the Kangaroo. Aboriginal families utilise the area for fishing and foraging and to pass their knowledge of this Dreamtime story on to their children (Dames & Moore 1997).

Other sacred sites in the vicinity of the subsea pipeline route include three rocky areas or shoals on the western side of the Harbour, and an underwater sand and rock bar outside the mouth of the Harbour north of Cox Peninsula.

3.6.14 Non-Aboriginal cultural heritage

Terrestrial heritage sites

There are several non-Aboriginal historical sites on Middle Arm Peninsula. These are related to World War II activities in the area and consist of five anti-aircraft searchlight batteries, one heavy anti-aircraft battery and the remains of the Z Force commando training camp that was mostly removed during the construction of ConocoPhillips' Darwin LNG plant (Bourke & Guse 2007; Crassweller 2001a, 2001b, 2002).

Three sites have been identified as non-Aboriginal historical sites within the onshore development area. The first site is located on the north headland of Blaydin Point and consists of a number of features relating to World War II occupation (Figure 3-51).

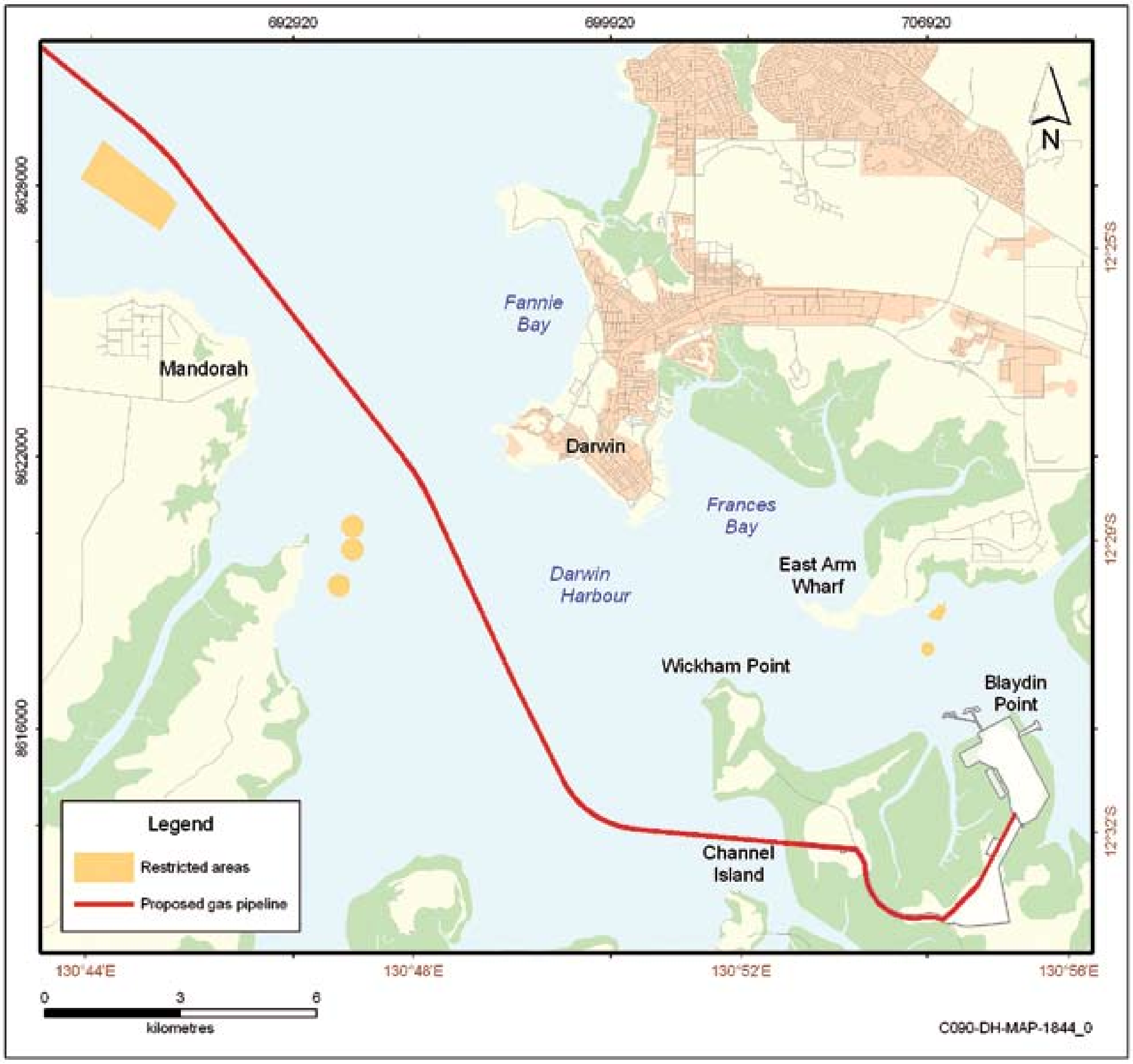


Figure 3-50: Aboriginal sacred sites in the nearshore development area

These include several concrete slabs, a possible searchlight foundation, a bomb-shelter trench and buried refuse pits containing postwar and World War II materials. In addition, two communication insulators and wire were found in trees south of the main site (Bourke & Guse 2007).

Maritime heritage sites

Maritime heritage sites in the vicinity of the nearshore development area are presented in Figure 3-51, and were located through literature review, geophysical surveys and follow-up diving surveys.

In February and March 2008, Fugro conducted geophysical surveys of the seabed in the nearshore development area (including the pipeline route through Darwin Harbour) to characterise seabed types and bathymetry for nearshore engineering purposes. The survey utilised a differential global positioning system (accuracy to 0.5 m or better), a Geoswath multibeam echo sounder and sidescan sonar system, a single-beam echo sounder and a boomer sub-bottom profiler. In addition to natural seabed features, the survey identified debris and wrecks on the seabed on 1:5000 scale drawings. Data were collected throughout the proposed disturbance area for the Project, up to the edge of mangroves and into minimum depths of 4.3 m above LAT. Small gaps of incomplete coverage occurred on very shallow sections of the intertidal flats and at a rocky shoal to the west of South Shell Island (Fugro 2008).

Where suspected wrecks or debris were identified by the geophysical survey, follow-up diving surveys were undertaken by TVDS to investigate the seabed feature. While some of these locations were natural features (rock ledges or sinkholes), others were confirmed as wreck sites (TVDS 2008). One such site, on closer

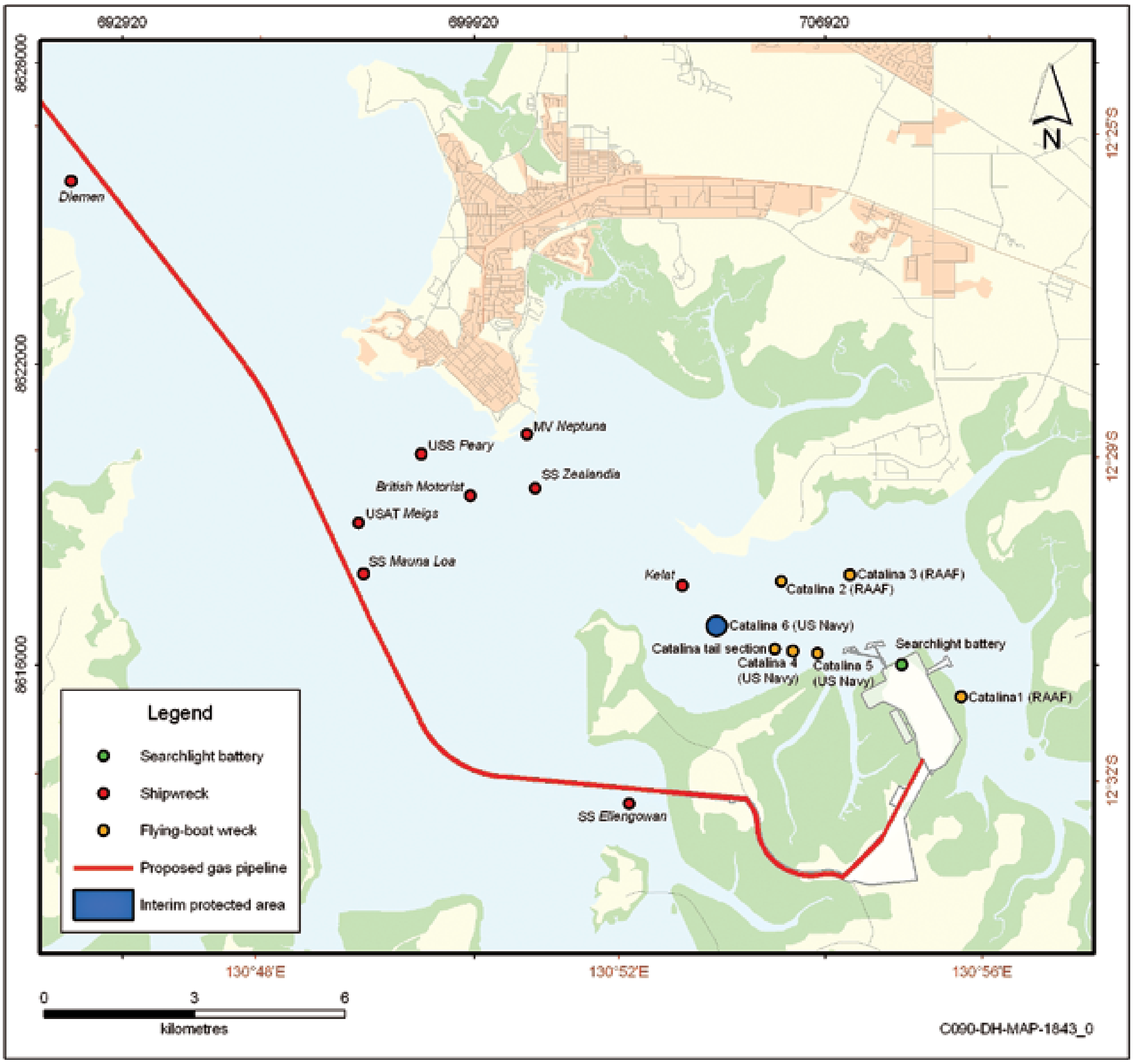


Figure 3-51: Non-Aboriginal heritage sites in the vicinity of the nearshore development area

inspection, was believed to be the wreck of a World War II Catalina flying boat from the United States Navy, and represented the first discovery of this particular heritage site (Catalina 6 in Figure 3-51). The discovery was reported to the Heritage Branch of NRETAS in May 2008.

In total, six Catalina flying-boat wrecks are located in the vicinity of the nearshore and onshore development areas. Three of the Catalinas were brought to Darwin by the United States Navy during World War II and were sunk during the Japanese air raids in February 1942. These wrecks (two PBY-4 Catalinas and one PBY-5) are protected by the United States *Sunken Military Craft Act* 2005 as well as by customary international law.

The other Catalinas (of the PBY-5 series) were owned and operated by the Royal Australian Air Force (RAAF) and were sunk in accidents. One of these ("Catalina 1") crashed on take-off in 1945, and is located in the mangroves on the east side of Blaydin Point.

The Heritage Branch of NRETAS has indicated that there may be heritage values associated with all the Catalina wrecks, and these are currently under assessment. An "interim conservation order" was placed on the newly discovered wreck of Catalina 6, under the *Heritage Conservation Act* (NT), in February 2009.

A number of other World War II shipwrecks are located near the pipeline corridor through Darwin Harbour, including the SS *Mauna Loa*, the tanker *British Motorist*, the USAT *Meigs*, the MV *Neptuna*, the SS *Zealandia* and the USS *Peary*. These were sunk as a result of a raid by Japanese forces on Darwin Harbour in February 1942.

The prawn trawler *Diemen* is also located in this area; it was sunk during Cyclone Tracy in 1974.

The SS *Ellengowan* is the oldest known shipwreck in Darwin Harbour and is one of the earliest examples of shipping associated with European settlement in the area. It is a unique example of nineteenth-century maritime history in the Northern Territory and its conservation values are rated highly because of its age and construction. It is one of only two known examples of transitional sail–steam iron-hull schooners (NRETA 2007b). As it is more than 75 years since the date of its loss (in 1888), the SS *Ellengowan* is protected under the *Historic Shipwrecks Act 1976* (Cwlth) and the *Heritage Conservation Act* (NT). It was placed on the Northern Territory Heritage Register in 1995. The wreck is located south of the proposed pipeline shore crossing for the onshore processing plant.

The wreck of the coal barge *Kelat*, built in 1881, is also located near the nearshore development area. It was damaged during the Japanese air raid on Darwin in 1942 and sank five days later.

3.6.15 Noise

Noise emissions in the Darwin and Palmerston areas are typical of urban areas with moderate to high levels of development. Major noise sources that commonly affect the community include traffic, noise from industrial or construction sites, and occasional aeroplane traffic from Darwin International Airport and RAAF jets flying through the area.

As part of the environmental impact assessment for the Project, ambient noise levels were measured by SVT Engineering Consultants in May 2008 at two locations selected in consultation with NRETAS (SVT 2009b) (see Appendix 20 for the full report). These sites are considered representative of residential areas in Darwin and Palmerston:

- O'Ferrals Road, Bayview Haven—approximately 2.5 km to the north-east of the Darwin CBD and 10 km to the north-west of the onshore development area
- Constance Court, Palmerston—approximately 5.5 km to the north-east of the onshore development area.

The $L_{A\,90}$, the noise level exceeded for 90% of the time, recorded at O'Ferrals Road was 37.3 dB(A), while the $L_{A\,10}$, the noise levels exceeded for 10% of the time, could rise to 43.5 dB(A) on occasion. At Constance Court the $L_{A\,90}$ was 39.9 dB(A), rising to an $L_{A\,10}$ of 48.9 dB(A).

The noise-logging data at both locations were very consistent throughout the fortnight monitoring period, indicating stable weather conditions. The results also showed a daily cycle of higher noise levels during the day and lower levels at night, typical of human activity patterns in urban environments (SVT 2009b). For reference, noise levels of 60 dB can be generated by normal conversation between people, 80 dB would be generated by heavy traffic and 90 dB would be emitted from a lawn mower.

3.6.16 Aesthetics and light

The visual amenity of Darwin Harbour is an important community value, which is closely linked with the recreation, tourism and residential values of the area. The shoreline around the Harbour contains relatively large tracts of undeveloped land, mainly comprising tidal flats vegetated by mangrove stands. The shoreline of Middle Arm is almost completely undeveloped, while some residential, industrial and infrastructure development has been undertaken along the shores of East Arm.

Major man-made features of the shoreline in the Harbour include the following:

- ConocoPhillips' Darwin LNG plant on Wickham Point approximately 5 km to the west of Blaydin Point
- East Arm Wharf on the northern shoreline, approximately 3 km away from Blaydin Point across the waters of East Arm
- Darwin's CBD on the eastern side of the mouth of the Harbour
- suburban developments from Darwin in the north to Palmerston in the east of the Harbour shoreline. A small residential area also exists in Mandorah, on the western side of the mouth of the Harbour.

These man-made features also represent the major sources of artificial light around the Harbour, along with beacons throughout the Harbour that are used for shipping navigation. These light sources contribute to an overall light "glow" from the city area which is visible (if very faintly) from up to 40 km away.

3.7 Economic environment

This section describes the current economic conditions in the Northern Territory, particularly the Darwin region, with reference to the national Australian economy.

3.7.1 National oil and gas industry

Australia has in recent years experienced growth in oil and gas exploration and production in order to meet increasing demand for energy, particularly from overseas markets. Australia is the world's fifth-largest LNG exporter after Qatar, Malaysia, Indonesia and Algeria. According to EnergyQuest, Woodside expects LNG demand to double over the next 10 years while forecast supply has been lowered (AER 2007). Energy export projects are being developed at a rapid pace in north-west Western Australia and the Northern Territory.

The majority of the known natural gas reserves in Australia are found offshore from central and north-west Western Australia in the Carnarvon, Browse and Bonaparte basins. Existing exploration and production in these three areas may be summarised as follows:

- Carnarvon Basin: located in the Indian Ocean, this area holds about 60% of Australia's known conventional natural gas reserves and currently accounts for about 34% of gas produced for the Australian domestic market. The North West Shelf Joint Venture converts some gas produced from the Carnarvon Basin to LNG gas for export (646 PJ in 2005–06).
- Browse Basin: located in the Indian Ocean, this area contains significant contingent gas resources (i.e. resources that are potentially recoverable but only if a number of contingent hurdles are overcome) estimated at 31 000 PJ. INPEX's Ichthys Field lies in the Browse Basin.
- Bonaparte Basin: located in the Timor Sea, this area is estimated to contain a contingent resource of about 19 500 PJ, which is shared between Australia and East Timor. The Bayu–Undan gas and condensate field was the first field in the basin to produce gas, which is processed for export at ConocoPhillips' Darwin LNG plant. In September 2009 the Blacktip Field, operated by Eni Australia B.V., commenced production and Eni's gas-processing plant at Wadeye is now supplying domestic gas to the Northern Territory.

Smaller gas-producing areas around Australia include the Gippsland Basin in Victoria, the Cooper–Eromanga Basin in South Australia and Queensland, the Perth Basin in Western Australia, and the Bowen–Surat Basin in Queensland (ABARE 2008).

Production of natural gas in Australia is predicted to increase by 217% between 2004 and 2030 to meet growth in both domestic and international demand. Demand for gas is expected to be strong in the electricity generation, manufacturing and mining sectors, partly as a result of government climate change policy initiatives that favour natural gas use over coal. Projections of Australian natural gas production suggest that by 2029–30 total production will reach 5343 PJ, with 3650 PJ exported as LNG (Table 3-19) (Cuevas-Cubria & Riwoe 2006). This would make natural gas the fastest growing of all Australia's energy exports.

Table 3-19: Australian gas production projections

	2004–05	2029–30
Natural gas production	1685 PJ	5343 PJ
Net exports of LNG	576 PJ	3650 PJ

Source: Cuevas-Cubria and Riwoe 2006.

The majority of large importers of LNG are in the Asia-Pacific region, giving Australia a natural advantage in terms of short distance to key markets. In 2007, Australia exported LNG mainly to Japan and China, with smaller volumes exported to South Korea and Taiwan (BP 2008).

3.7.2 Darwin regional context

As described in Section 3.6.1 *Description of baseline*, the socio-economic baseline for this study has been defined by the ABS statistical subdivisions of Darwin City and Palmerston – East Arm (see Figure 3-46), which are the two major population centres in the Darwin region. Background data on the economic environment in these areas are provided in the following section.

Labour force

In 2006, the labour force in Darwin City totalled 38 998 people, with a labour force participation rate of 65.6% (ABS 2007a). This is higher than both the Northern Territory and Australian participation rates of 64.2% and 60.4% respectively, and indicates a strong working population. Over the ten years to 2006, the labour force of Darwin has grown by only 800 persons, or 2.1%, while employment has increased by 2277 jobs and unemployment has more than halved. This indicates that many people in the labour force have benefited from an increase in jobs available, with almost 1500 people moving out of unemployment. As of 2006, the unemployment rate in Darwin stood at 3.6%, below the rate of 5.2% experienced overall in Australia. In fact, over time Darwin has tended to have lower unemployment than other areas of Australia—this has been the case in all three population censuses since 1996 (ABS 2007a).

The labour force statistics for Palmerston – East Arm are indicative of an area undergoing rapid expansion. Palmerston began to be developed in the 1980s as the supply of residential land in Darwin started to diminish, and it is now the primary urban development area of the Darwin region. The total population of Palmerston – East Arm almost doubled between 1996 and 2006 (ABS 2007a). In 2006, there were 11 406 people in Palmerston – East Arm participating in the labour force, with a participation rate of 66.2%—even higher than the participation rate in Darwin. Between 1996 and 2006, the Palmerston – East Arm labour force grew by 90.4% and the number of people employed effectively doubled. Over the same period, unemployment fell from 8.7% to 4.1%, below the Australian average of 5.2% but still slightly above Darwin's rate of 3.6% (ABS 2007a).

Employment by industry

City of Darwin

Employment in the City of Darwin is spread across a range of areas, with a particular focus on the service industries (such as finance, hospitality, real estate, and administration). The largest industry employer in 2006 was in the area of public administration and safety, which employed 7172 people (ABS 2007a) (see Figure 3-52). There is a large ADF presence in Darwin, and it is likely that many of those people employed in public administration and safety are associated with the ADF. As Darwin is the seat of government for the Northern Territory, there are also many government officials located in the city.

For many Territorians, Darwin is a regional hub where people come to shop, to access specialised health services, or to study at the senior schools or university. For this reason there are high levels of employment in the retail trade (3563 people), health care and social assistance (3519 people), and education and training (3268 people). Given Darwin's attraction as a tourist destination, the employment of 2560 people in the accommodation and food services industry is not surprising. There is also a strong construction industry (2665 people) (ABS 2007a).

Over the past decade in Darwin City, only the public administration and safety sector has shown a significant change in employment, with an increase of nearly 22% between 2001 and 2006 (ABS 2007a). Some growth has also occurred in education and training, transport, postal and warehousing, and retail trade. The construction sector has experienced some employment volatility since 1996, with employment falling sharply by 30.4% between 1996 and 2001, but rebounding by 41.2% by 2006 (ABS 2007a). This is consistent with the cyclical impacts when major projects end and new ones begin.

Palmerston – East Arm

Like Darwin, the largest industry employer in Palmerston – East Arm is public administration and safety—in 2006, nearly 1 in 4 people were employed in this industry (2593 people). As with Darwin, much of this employment can be attributed to the defence

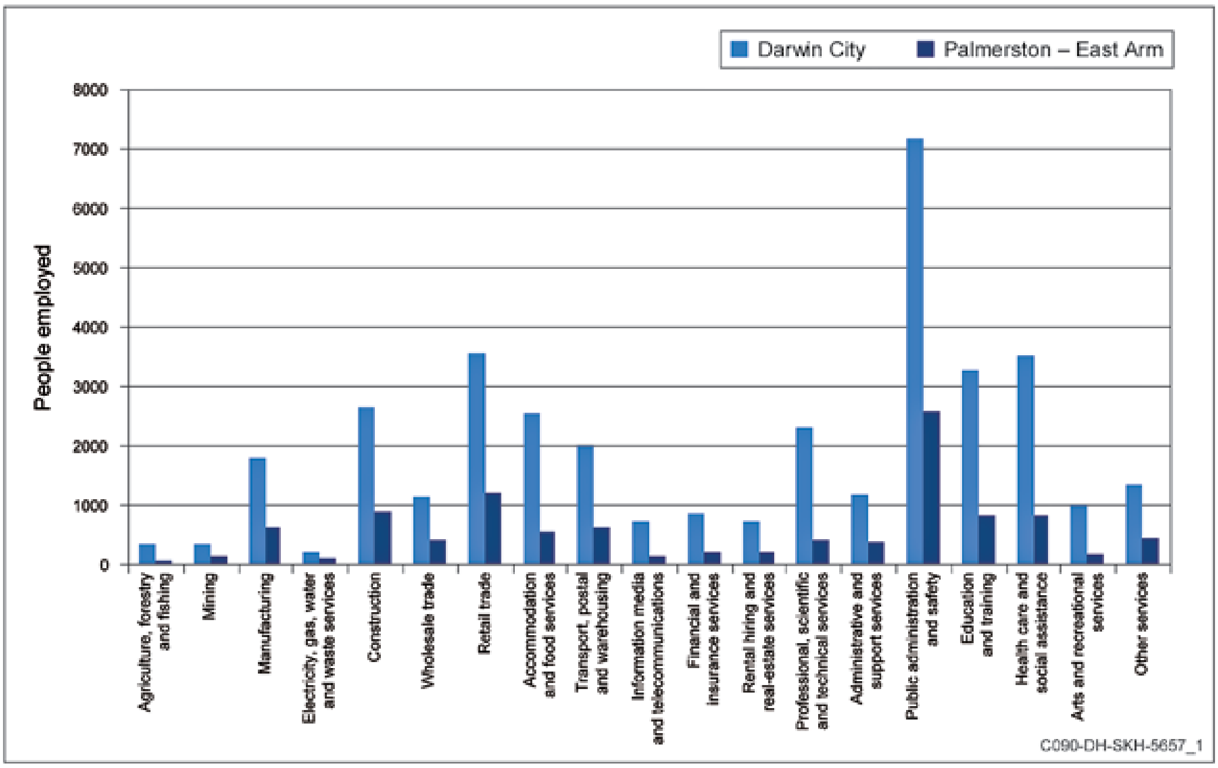


Figure 3-52: Employment by industry in 2006 in Darwin City and Palmerston – East Arm

sector, in particular to the Robertson Barracks situated near Palmerston. Other important industries in Palmerston – East Arm include the retail trade (1193 people), construction (881 people), health care and social assistance (832 people) and education and training (829 people) (see Figure 3-52) (ABS 2007a).

Over the past decade, all industry sectors in Palmerston – East Arm experienced an increase in the total number of people employed, although rates of growth varied. Public administration and safety experienced the largest rate of employment growth (ABS 2007a).

Employment by occupation

The spread of occupation types in Darwin City is very similar to the Australian average. In 2006, professionals were the largest employment category, followed by clerical and administrative workers, technicians and trades workers, managers, and community and personal service workers, among others (see Figure 3-53) (ABS 2007a).

In the ten years to 2006, the proportions of people in each occupation category has changed very little. There was a drop in the number of technicians and trades workers, and machinery operators and drivers, in line with the general downward trend around the Northern Territory and Australia (ABS 2007a).

Palmerston – East Arm is characterised by lower proportions of professionals and managers than Darwin, the Northern Territory and Australia. In 2006, clerical and administrative workers made up the largest employment category by occupation, followed by technicians and trades workers, and community and personal service workers (Figure 3-53) (ABS 2007a).

Over the ten years between 1996 and 2006, the number of community and personal service workers in Palmerston – East Arm has more than doubled. This increase is likely to be partly attributable to the inflow of defence personnel between 1996 and 2001 when the Army Presence in the North (APIN) program was very active and personnel were being transferred to the area from elsewhere in Australia.

Wealth and incomes

In 2005–06, the mean household income per week in the Darwin region was $1675, which is higher than the Australian average of $1410 per week (ABS 2007b). Disposable household income was also higher at $730 per week, compared with $678. These results are likely to be in part attributable to the younger population and larger working population in the area. The proportion of households in the area receiving government pensions or allowances as their main source of income was the lowest in the country, at 8.5% of total households. This estimate has a large standard error of 25–50% and should not be considered reliable. However even if the proportion of households receiving government pensions was doubled, Darwin would still have the second-lowest proportion of such households in the country, behind Canberra (ABS 2007b).

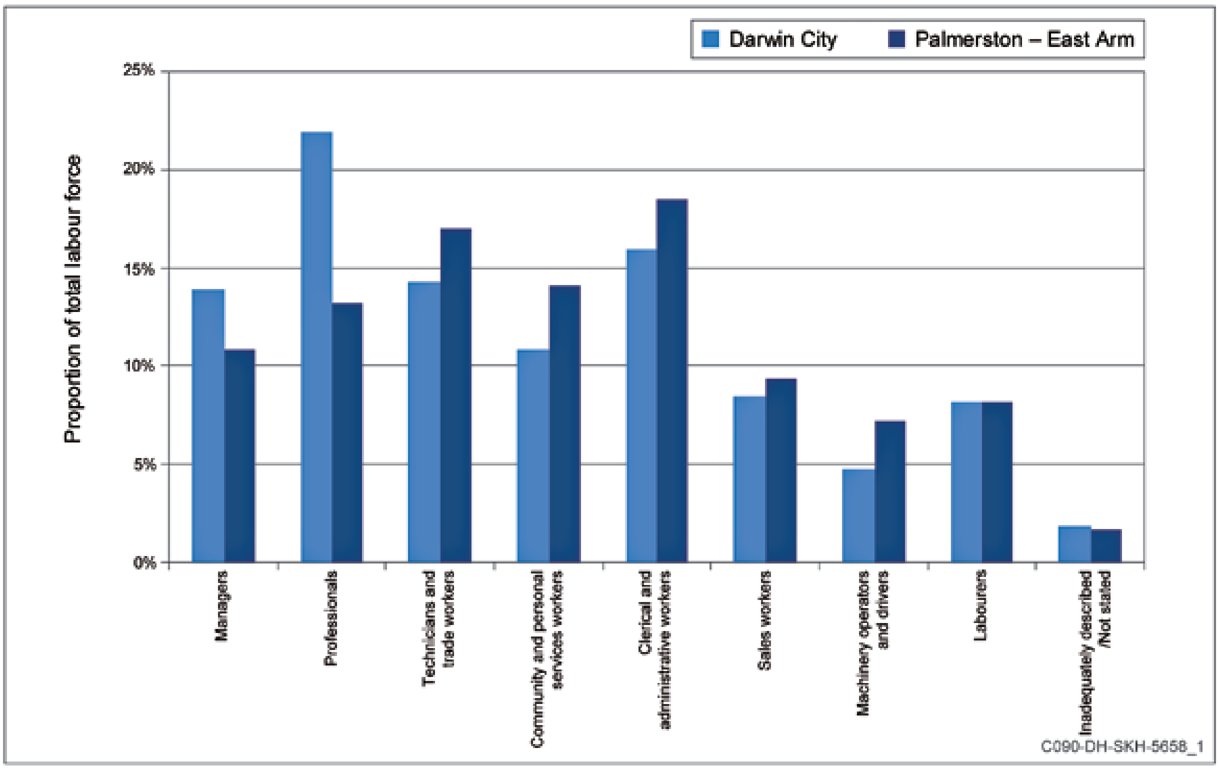


Figure 3-53: Employment by occupation type in Darwin City and Palmerston – East Arm, 2006

Despite these relatively high levels of income, the population of the Darwin region is not necessarily "wealthy". Mean household net worth, an estimate of a household's assets such as property and investments, was the lowest in the country, at $411 569. This finding would be related to Darwin having the highest proportion of renters in the country (38.6% of total households) (ABS 2007b). In addition, the number of Darwin households in 2006 experiencing one or more cash-flow problems is higher than the national average, at 22.7% compared with 17.6% nationally (ABS 2007c). Cash-flow problems include being unable to pay telephone bills on time or having to borrow money from friends or family.

3.7.3 Regional industry

The Northern Territory has a relatively diverse economy, with a strong reliance on the mining industry. "Value added" is a measure of output, and refers to the additional value of a commodity over the cost of commodities used to produce it from the previous stage of production. In the Northern Territory economy, over a quarter of value added comes from mining; however the service industries (e.g. finance, hospitality, real estate, administration) also play a major role in the economy. Other industries of importance include construction, government administration and defence, and manufacturing (Table 3-20) (ABS 2007d).

Further discussion on key industries from the Darwin region is provided below. These industries are particularly relevant to the Project as they utilise Darwin Harbour and include Defence, tourism, fishing, construction, manufacturing, and transport.

Defence

The Australian Defence Force has a key presence in the Northern Territory, with around 5600 personnel stationed there in 2006. This represents approximately 10% of the total operational personnel of the ADF. When the families of personnel are included, the total number of people associated with the ADF in the Northern Territory is over 13 000, or 6.5% of the Northern Territory population. All ADF operations in northern Australia, including north Queensland and northern Western Australia, are controlled by Headquarters Northern Command in Darwin. Robertson Barracks in Palmerston is the largest armoured fighting vehicle base for the ADF. Other key defence facilities in and around Darwin include Larrakeyah Barracks, the naval base HMAS *Coonawarra*, Defence Establishment Berrimah and RAAF Base Darwin (DBERD 2006).

Table 3-20: Northern Territory value added by industry, 2006–2007

Industry sector	Value added 2006–2007 ($ million)	Percentage of total industry value added
Agriculture, forestry and fishing	301	2.4
Mining	3 284	25.8
Manufacturing	719	5.7
Electricity, gas and water	167	1.3
Construction	985	7.7
Wholesale trade	265	2.1
Retail trade	551	4.3
Accommodation, cafes and restaurants	329	2.6
Transport and storage	554	4.4
Communication services	273	2.1
Finance and insurance	297	2.3
Property and business services	964	7.6
Government administration and Defence	1 039	8.2
Education	541	4.3
Health and community services	706	5.5
Cultural and recreational services	203	1.6
Personal and other services	278	2.2
Rental property (residential)	1 268	10.0
Total industry gross value added	**12 724**	**100.0**

Source: ABS 2007d.

The APIN program resulted in the transfer of many serving ADF personnel from Holsworthy Barracks in New South Wales and Puckapunyal in Victoria to the Northern Territory during the 1990s. Between 1992 and 2006, the number of personnel stationed in the Territory more than doubled. This placed pressure on housing stocks and was a factor influencing the Northern Territory's housing boom in the mid- to late 1990s. In 2005, Defence Housing Australia (DHA) held approximately 1750 properties in the Darwin area and it is currently investing in residential developments in the suburbs of Lyons and Muirhead to boost these stocks (DBERD 2006).

The amount of money spent by the ADF in the Northern Territory totalled $1.08 billion in 2006–07. This is direct expenditure only, and the actual value of the defence industry to the Northern Territory is larger than this. The territory is host to national and international defence exercises such as Exercise Pitch Black, a joint operation between the Australian, French, Thai, Singaporean, UK and US air forces. In addition, overseas naval vessels regularly visit the Port of Darwin; in 2007, 47 major naval vessels visited Darwin, contributing to the Northern Territory economy through sailors' shore leave and ship servicing expenditure. The local defence support industry in the Northern Territory was estimated to have obtained approximately $200 million worth of defence contracts in 2006–07, and provides support in the areas of logistics, vehicle maintenance, communications, radar monitoring, ship maintenance, infrastructure construction and electronic systems design (Northern Territory Government 2008b).

Tourism and recreation

The Northern Territory is divided into nine tourism regions. Darwin Harbour, the cities of Darwin and Palmerston and the outer rural area around the cities are all contained in the "Darwin" tourism region. This region, although relatively small in size, holds a large share of tourism in the territory. Between 2005 and 2007, the Darwin tourism region received an average of 720 000 visitors per year, which represents 51% of total visitors to the Northern Territory (Tourism NT undated).

In total, there were 1 398 000 visitors to the Northern Territory during the year ending March 2009. The average length of stay was 6.9 nights and visitor expenditure was estimated at $1660 million. Almost half of the visitors to the Northern Territory come from interstate, while intra-Territory and international visitors made up nearly one-third and one-quarter of the total respectively. Most interstate and international visitors travel to the Northern Territory for a holiday, while Territorians are more likely to travel to visit friends and family or for business purposes (Tourism NT 2009).

Tourism is a composite industry made up of a variety of service industries such as accommodation and transport. It is a key contributor to the economy of the Northern Territory and in 2003–04 tourism contributed $615.7 million to Northern Territory gross value added (GVA). This equates to 6.7% of total economic activity and is almost twice the level contributed by the national tourism industry to the Australian economy (Spurr et al. 2007).

Some sectors in the Northern Territory are more dependent on tourism than others—accommodation, cafes and restaurants are particularly exposed (Tourism NT undated). In the Northern Territory in December 2007 there were 178 accommodation providers, employing 3591 persons.[9] Takings from accommodation for the quarter ending December 2007 were estimated at $61.1 million (ABS 2008c).

Construction

The construction industry in the Northern Territory has undergone a rapid expansion in recent years, with spikes of intense activity in some years (see Figure 3-54). The value of engineering construction activity increased from $59 million to almost $290 million between 2000 and 2008 (ABS 2008d). The large spike between 2001 and 2002 was largely because of the construction of the Adelaide–Darwin railway line, while other major projects such as the construction of the ConocoPhillips Darwin LNG plant and the expansion of Alcan Gove's refinery have also contributed to strong demand for construction activity.

Since the completion of these major projects, the construction industry has started to decline. The Darwin LNG plant was completed in 2005 and Alcan's expansion of the Gove refinery was completed in 2007. As shown in Figure 3-54, the value of engineering construction work done began to decline from around mid-2006. This trend is projected to continue unless another major project commences (Northern Territory Government 2008c).

Major projects such as those mentioned above are important contributors to the growth of the construction industry in the Northern Territory, but they are not the only factor involved. Between 2000 and 2008, residential building activity has approximately doubled, with construction work on residential buildings worth $51.1 million in 2000 and $102.3 million in 2008 (ABS 2008e).

A significant proportion of the rise in residential building activity can be attributed to the involvement of the DHA in the development of new residential subdivisions in Darwin. The $280-million DHA-funded development of the suburb of Lyons, for instance, commenced in 2006 and was formally opened in June 2008; construction of houses in that suburb will be completed in 2011 (DHA 2008; Northern Territory Government 2008b). The development of the neighbouring suburb of Muirhead, beginning in 2010, will provide continued opportunity for growth in the residential building industry.

9 These figures should be used with caution, as some data were not publicly released in order to protect business confidentiality.

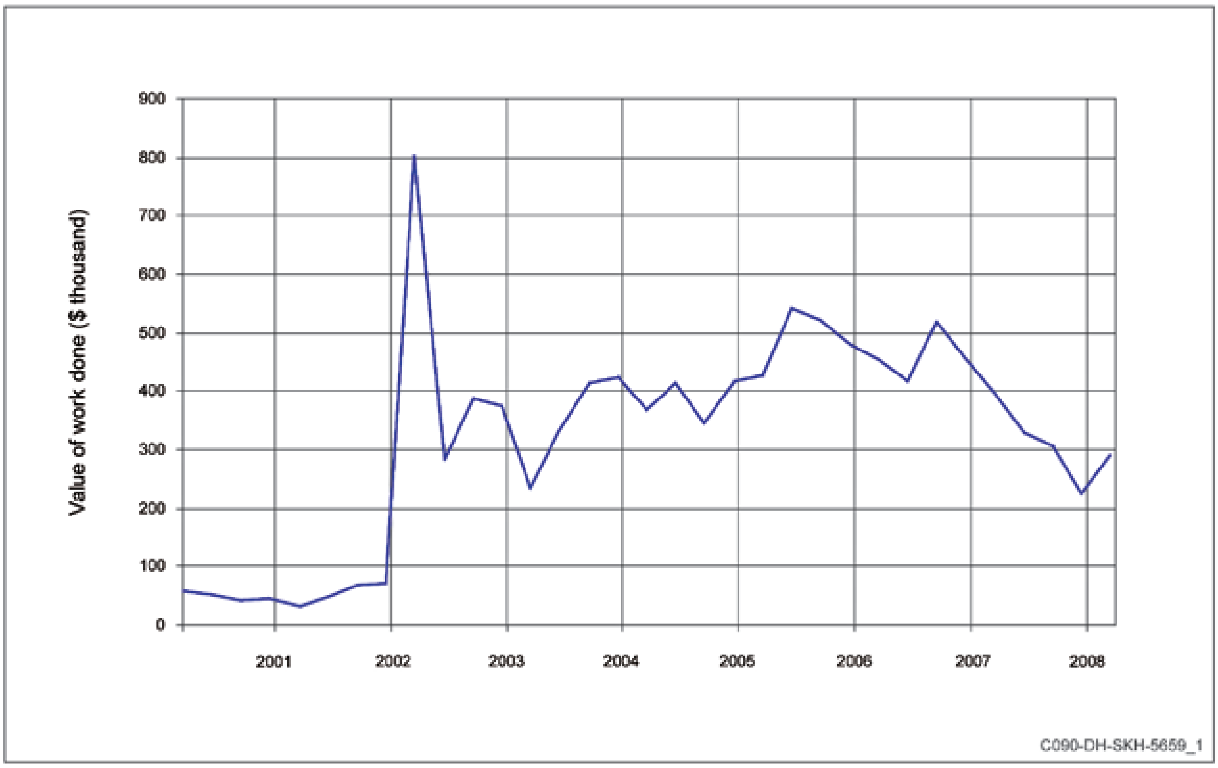


Figure 3-54: Engineering construction activity in the Northern Territory, 2000–2008

Manufacturing

The manufacturing industry in the Northern Territory is relatively small. In 2006–07 it accounted for only 5.4% of gross state product and employed 4600 people (Northern Territory Government 2009d). The sector is dominated by the manufacture of metal products, and the manufacture of petroleum, coal, chemical and associated products. These categories together account for over half of the gross value added of the manufacturing sector.

The two major projects that have contributed to the dominance of the metal product and petroleum manufacturing sectors are the Alcan Gove alumina refinery on the Gove Peninsula in east Arnhem Land and the Darwin LNG plant at Wickham Point in Darwin Harbour. With the completion of its expansion project in 2007, the refinery was expected to produce 3.0 Mt/a of alumina for export in 2007–2008, increasing to 3.5 Mt/a in 2008–2009 (Northern Territory Government 2008d). The Darwin LNG plant began operations in February 2006 and has a production capacity of 3.7 Mt of LNG per annum. Japanese buyers are contracted to buy up to 3.3 Mt/a of the LNG, providing an export income of approximately $500 million every year (Wilson 2007).

3.7.4 Commercial fishing and aquaculture

Fisheries

The offshore and nearshore development areas are located within the boundaries of a number of commercial fisheries managed by the Commonwealth, Western Australia and the Northern Territory. Commercial fisheries cover very large areas of the offshore and nearshore environment, but the actual fishing effort applied in each fishery is often concentrated on particular sites. In addition, the number of licences issued for each fishery varies, and in some cases can be fewer than 10. This has the effect of reducing the likelihood that Project activities would impact these commercial operations.

The following commercial fisheries overlap the offshore development area at the Ichthys Field:

- North West Slope Trawl Fishery (Commonwealth): This is located in deep water off north-west Western Australia, extending seaward from the 200-m isobath to the edge of the Australian Fishing Zone. The Ichthys Field is located close to the north-east boundary of this fishery. Seven fishing permits are issued for the fishery. Fishing is conducted using demersal crustacean trawling, which involves towing a net close to the seabed just above the benthic zone (Granherne Pty Ltd 2007).

- Northern Demersal Scalefish Fishery (offshore zone only; Western Australia): This is located off the north coast of Western Australia. As of 2008, 11 offshore permits had been issued for the fishery, which utilises traps or handlines and droplines (Fletcher & Santoro 2008).
- Western Tuna and Billfish Fishery (Commonwealth): This fishery extends throughout the coastline of the Northern Territory, Western Australia and South Australia. Fishing effort data from 2001 for both domestic and Japanese operators in this fishery indicated that the Project's offshore development area is well outside the areas of fishing activity, which mainly occur to the west in deep offshore waters. Fishing is conducted by pelagic longlining in waters beyond the continental shelf break (Granherne Pty Ltd 2007).
- Southern Blue Fin Tuna Fishery (Commonwealth): This extends around the entire Australian coast to the boundary of the Australian Fishing Zone (approximately 370 km offshore). Longline fishing for southern bluefin tuna occurs primarily off southern New South Wales and to a lesser extent off southern Western Australia, distant from the onshore development area (AFMA 2009a).
- Mackerel Managed Fishery (Western Australia): This is located throughout the nearshore and offshore waters of the Kimberley coast usually around reefs, shoals and headlands. There were 22 fishing permits active in 2008, and fishing is mainly by surface trolling or by hand line in coastal waters (Fletcher & Santoro 2008).

All of these fisheries also coincide with the gas export pipeline route at its western end. In its eastern sections approaching the Northern Territory, the pipeline also crosses other commercial fisheries. These are as follows:

- Kimberley Prawn Managed Fishery (Western Australia): This is located off the Kimberley coast of Western Australia and extends into offshore waters. As of 2008, there were 137 licences but only 20 boats active in the fishery. The main fishing method is otter trawling, which involves towing a net along the seabed (Fletcher & Santoro 2008).
- Northern Prawn Fishery (Commonwealth): This extends from the coast to the boundary of the Australian Fishing Zone, from the northern Kimberley coast into the Northern Territory. In 2008–09 there were 25 "statutory fishing right" holders in the fishery. The main fishing method is otter trawling, which involves towing a net along the seabed (AFMA 2009b).
- Northern Shark Fisheries (Western Australia, Joint Authority): These fisheries comprise the state-managed Western Australian North Coast Shark Fishery, located off the Pilbara and western Kimberley coast, and the Joint Authority Northern Shark Fishery in the eastern Kimberley. Nine licences (shared by 11 boats) have been issued for the fishery and the primary fishing method is demersal longlining (Granherne Pty Ltd 2007).
- Coastal Line Fishery (Northern Territory): This fishery lies within 15 nautical miles of the coast. In 2007 there were 24 active licences and fishing effort, which was highest in the early 1990s, has been decreasing for the last four years (DRDPIFR 2008).
- Coastal Net Fishery (Northern Territory): This fishery occurs within three nautical miles of the coast. Commercial fishing effort is low, with only five licences at the end of 2007 because of a voluntary licence buy-back scheme. Licensed fishing gear includes coastal nets, cast nets and a limited number of gill nets (DRDPIFR 2008).
- Offshore Net and Line Fishery (formerly Shark Fishery) (Northern Territory): This extends from the coast to the Australian Fishing Zone boundary, but with most fishing effort within 12 nautical miles of land. Fishing methods include longlines or pelagic nets, but no bottom-set gill nets. There are 17 licences permitted to operate of which 11 were active in 2007. Fishing effort is dependent on operational and market conditions and has been decreasing since 2003 (DRDPIFR 2008).
- Spanish Mackerel Fishery (Northern Territory): This extends from the coast to the Australian Fishing Zone boundary. Most fishing effort occurs near the coast, around reefs, headlands and shoals, using heavy troll lines. In 2007 there were 19 licences of which 16 were actively operating (DRDPIFR 2008).

Very little commercial fishing activity takes place in the Project's nearshore development area (inside Darwin Harbour), mainly because of the high levels of recreational fishing that occur in the area. Operators in the Coastal Line Fishery, which is managed by the Northern Territory, are permitted to fish in Darwin Harbour but rarely do so. Similarly, the Aquarium Fishery includes Darwin Harbour but only two operators actually fish in the area. Darwin Harbour provides a base for vessels operating in fisheries throughout the Northern Territory and northern Western Australian waters (K Sarneckis, Northern Territory Seafood Council, pers. comm. March 2009).

The DoR manages wild-harvest fisheries in the Northern Territory, which in 2007 had a gross value of production of $30.1 million at point of first sale. The three highest catch value wild-harvest fisheries in the Northern Territory in 2007 were mud crab, barramundi and the Timor Reef fishery (DRDPIFR 2008), none of which occur to any significant extent in the offshore or nearshore development areas.

Aquaculture

The aquaculture industry in the Northern Territory in 2008 was worth $21 million at point of first sale. The industry is dominated by the pearling industry, which had a gross value of production of $16.3 million and employed 114 people in 2008. The majority of pearl oysters are now reared in hatcheries, with very few taken from the wild (DoR 2009c).

Barramundi farming is the second-largest aquaculture fishery by value, with a gross value of production of $4.3 million. In 2008, all four barramundi-farming operations in the Northern Territory were pond-based, with no sea-cage operations. Mud crabs were farmed on a small scale, including in one pond-based farm located near Darwin Harbour, but these ceased operations in 2008 (DoR 2009c).

Two commercial pearl culture leases exist near Middle Arm, although these are not currently in operation. Another pearling lease currently exists in Lightning Creek on the west side of Blaydin Point; it is not known whether this lease will continue to be used.

The Darwin Aquaculture Centre is situated on Channel Island, west of Middle Arm Peninsula. The centre was established in 1998 and provides for commercial barramundi fingerling production, as well as aquaculture research. In 2008 it accommodated 16 staff and 2 postgraduate students (DoR 2010).

3.7.5 Industrial infrastructure and services

Utilities

Power and water services to the Darwin area are primarily provided by the Power and Water Corporation. The corporation operates the 254-MW Channel Island gas turbine generator and has allocated over $126 million to build a new power station at Weddell. The new power station is being built to service the growing energy demands of Darwin and Palmerston.

Ninety per cent of Darwin's water supply is obtained from the Darwin River Dam, which has a capacity of 265 000 ML. Additional water supplies are obtained from groundwater. In 2006 licensed extraction from these sources provided 46 420 ML/a and demand was 40 000 ML/a. To provide for future population growth in the Darwin area, new water supplies will need to be found or water usage reduced. Darwin residents currently have the highest water consumption per capita in Australia, and reducing their use to the national average will delay the need for alternative water supplies for potentially another 50 years (Power and Water Corporation 2006b).

There are currently no electricity or water facilities at Blaydin Point. The nearest distribution lines are along Wickham Point Road and new lines would have to be constructed to connect these to the onshore development area.

Rail transport

The construction of the railway from Adelaide to Darwin has created a new link in the transport network, allowing goods to be transported easily to Darwin for export overseas. The first train between the two cities ran in 2004, taking just two days to cross the continent. Previously there were two options for the transport of goods: from Adelaide to Alice Springs by rail and then from Alice Springs to Darwin by road, or using sea freight to Darwin. But the rail-and-road option was not economically feasible for bulk commodities such as minerals, while transport by sea was relatively slow.

The new rail link is operated by FreightLink. It carries around 800 000 t of intermodal freight, 70 000 t of bulk liquids and more than 3 Mt of bulk freight per year. The company operates six services a week between Darwin and Adelaide (FreightLink 2009).

The advantages of the new rail service include cheaper and more competitive bulk freight options for exporting industries such as mining and agriculture (e.g. live cattle), and logistical support for the ADF with the movement of troops and matériel.

FreightLink has already entered into freight contracts with several mining companies to transport manganese and iron ore to the Port of Darwin from remote sites in central Australia. A report by Access Economics in 1999 suggested that the economic benefits of the railway would be significant, with Northern Territory gross state product increasing by $3 billion (AustralAsia Railway Corporation 2003).

Port and shipping

The Port of Darwin is Australia's gateway to the markets of South-East Asia. Geographically it is closer to South-East Asia than any other port in Australia. The port is managed by the Darwin Port Corporation as a Government Business Division of the Northern Territory Government, and answers to the Minister for Infrastructure and Transport (Darwin Port Corporation 2009).

It is Australia's primary port for live cattle exports and also has facilities for container and general cargo, and bulk commodities such as iron ore and manganese. It is Australia's second-largest LNG exporting facility and received 115 tanker vessel calls in 2008–09 (Darwin Port Corporation 2009). In addition to international trade services, the port also includes a mooring basin for the Darwin-based fishing fleet and smaller vessels, the Darwin Wharf Precinct (a retail, restaurant and tourism complex), and a naval and cruise ship berth (Darwin Port Corporation 2008).

As shown in Figure 3-55, trade at the Port of Darwin has been increasing markedly since 2001. In 2007, $24 million was spent on a new bulk minerals export facility at East Arm Wharf, which is utilised by mining projects (Northern Territory Government 2008e).

Trade from the Port of Darwin is also increasing as a result of the new rail link from Adelaide to Darwin, which connects East Arm Wharf to the national rail network.

In 2008–09, total trade through the port was approximately 3.8 Mt, an increase of 38% on the previous year. During 2007–08 and 2008–09 exports outweighed imports, mainly because of large increases in the trade of dry bulk goods. This cargo segment represented 87% of the exports shipped from the port and consisted mainly of iron ore and manganese. Livestock exports represented 5.7% of the export total volume and petroleum represented 2.6% (Darwin Port Corporation 2009). It is noted that exports from the Darwin LNG plant, which has its own port facilities, are not included in these summary values.

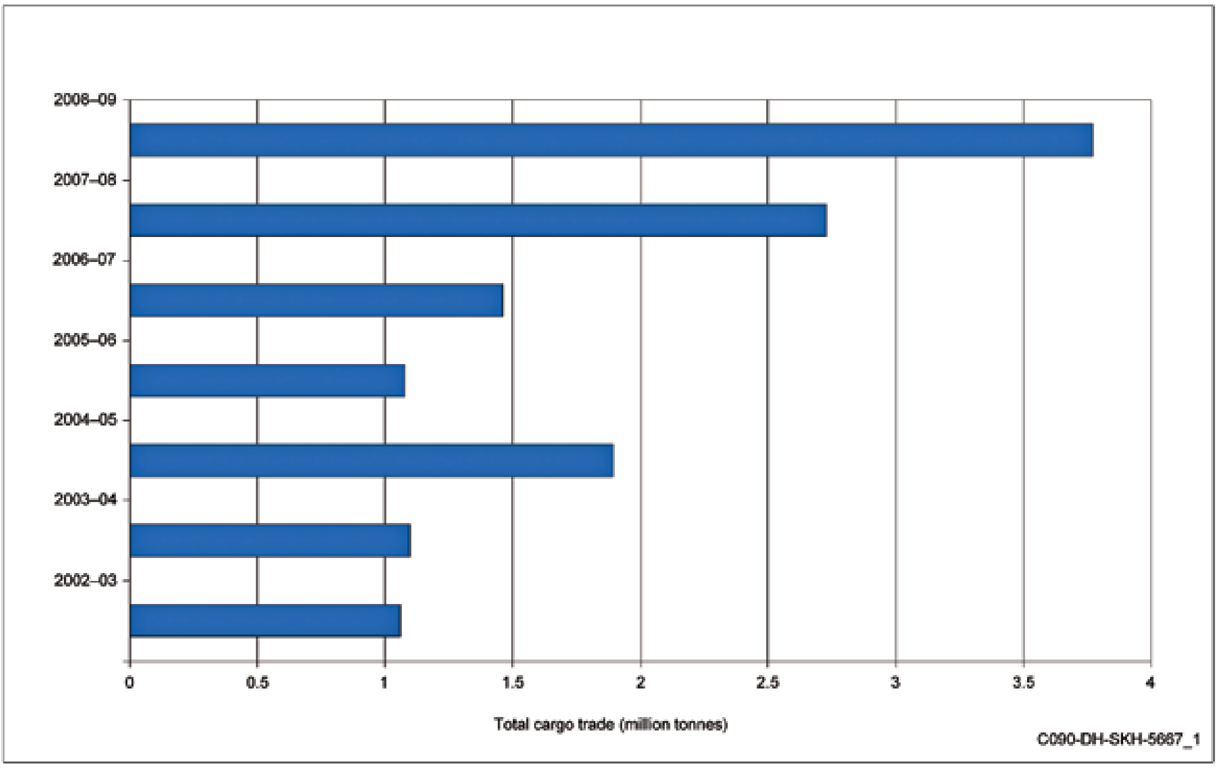


Figure 3-55: Total annual cargo trade at the Port of Darwin, 2001–2009

3.8 References

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