Marine Ecology

15.1 Introduction

Darwin Harbour is a large ria system, or drowned river valley, with an area of 500 km^2. Large tidal amplitude occurs in Darwin Harbour with ranges up to 7.5 m producing currents up to 2.5 m/s. From January to April freshwater flows to the harbour and estuarine conditions prevail. Darwin Harbour is divided into three main components: Middle Arm, West Arm and East Arm, where the project is located. The project will be on the south west part and the north side of the East Arm Peninsula.

Darwin Harbour has a complex assemblage of marine habitats such as rocky shores, mangroves and mudflats. The marine environment is complex and all these habitats can occur in a small area. The sides of the main drainage channels are generally rocky but the substrate varies from pavement covered with a thin layer of sand to beds of sediments varying from gravel to sand and silt. Extensive mangroves are found in the bays and protected areas throughout the intertidal zone with flats occurring in the lower intertidal zone. Many of these flats are mud; some have a rocky basement covered by a thin layer of sand and silt.

15.1.1 Marine Communities

Several types of ecological communities have been recorded in Darwin Harbour: rocky shore communities, hard coral communities, filter feeder communities (primarily soft corals and sponges), macroalgae communities, seagrass beds, soft sediment communities, mangrove communities and fish communities. Comprehensive mapping of marine communities on the eastern side of Darwin Harbour is included in INPEX Browse (2011).

Rocky shore communities

The general zonation of hard substrates in Darwin Harbour has been described by Pope (1967), Ferns (1996), Russell and Hewitt (2000) and in environmental impact assessments for proposed developments. Zonation patterns can be seen with few species in the upper intertidal and a greater number of species in the lower intertidal where conditions are not as extreme (URS, 2002).

In the intertidal area exposed rocks are mainly colonised by oysters and barnacles while crevices, holes and underside of rocks are colonised by small molluscs (*Nerita* spp. and *Thais* spp.) and isopod crustaceans. At mean sea level (low intertidal) blue-green algae and diatoms form a dark band across the rock bed. The lower intertidal is further divided into two zones: an upper zone that has molluscs and crustaceans, soft corals, sponges, turf and brown algae (*Padina* spp.) and the lower zone represented by subtidal species covering the rocks (hard and soft corals, sponges, crustaceans, anemones and macroalgae (Smit, 2003).

Hard coral communities

Hard coral communities are found from the lower subtidal to 5-10 m below lowest astronomical tide (LAT) in areas where there are strong currents. These coral species are tolerant to the variable salinity, high turbidity and sedimentation that exclude most coral species. A total of 123 species of corals have been recorded in Darwin Harbour (Wolstenholme, Dinensen and Alderslade, 1997).

Coral spawning is not known to have been observed in Darwin Harbour, although many of the species found reproduce by spawning elsewhere in the Indo-Pacific Region. Spawning in the NT aquarium has been observed around the full moon of October-November (Territory Wildlife Park (TWP), 2006).

Filter feeder communities

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 (40 genera) respectively. Their poor representation can be attributed to the turbidity of the water in the harbour and 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).

Sea whips and sea fans are generally restricted to areas of current sheltered from wave action. Sponges are commonly found in transition areas between hard substrates and soft substrates. Substrates dominated by gravel and / or shell grit or sand-silt are the most favourable to sponge larval settlement (Smit, 2003).

Macroalgae

Macroalgae are present in Darwin Harbour and are often located on platform crests generally a few metres on either side of the low water mark. Their abundance is seasonal, with turf algae dominating in October-December when the tidal range is at its greatest and low tides occur in the middle of the day causing the macroalgae to die back. During the dry season the larger macroalgae are more abundant. Macroalgae-dominated communities have been recorded in East Point Aquatic Life Reserve and at Weed Reef (Smit, 2003).

Seagrass

Within Darwin Harbour, the most extensive seagrass meadows are off Casuarina Beach and substantial seagrass meadows are not known to occur further south than in Fannie Bay (INPEX Browse, 2010).

Soft sediment communities

It is estimated that soft substrates cover about 80% of the available substrate of Darwin Harbour (McKinnon et al., 2006). The substrate consists of mud and muddy-sand in the intertidal and of various fractions of mud and sand in the subtidal and shifts to coarser sediments as it goes into the channel.

The intertidal communities are dominated by polychaete worms while the more diverse subtidal communities have polychaetes, crustaceans, echinoderms and sponges (Smit, 2003). It is estimated Darwin Harbour has approximately 600 polychaete species (most of which are scientifically undescribed), 1000 crustacean species and over 900 species of molluscs (McKinnon et al., 2006).

Table 15-1. 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

Taxonomic group	Number of species	Comments
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

Mangrove communities

Extensive areas of mangroves fringe much of the Darwin Harbour shoreline. These communities occupy 27,350 ha, mostly occurring on the portion of intertidal mudflats between Mean Sea Level and Mean High Water Springs (McKinnon et al., 2006, Semeniuk, 1985). Approximately 20,450 ha of mangroves occur within 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 (Water Monitoring Branch (WMB), 2005).

Mangrove species richness is high in Darwin Harbour with a total of 36 of the 50 mangrove plant species occurring in the harbour. Due to the seed or propagule dispersal mechanisms of mangroves it is not expected that any species will be restricted to Darwin Harbour or the project area at East Arm. No mangrove species occurring in Darwin Harbour are listed under either the NT TPWC act or the Commonwealth EPBC Act.

Mangroves support a rich and abundant suite of invertebrate fauna. Detailed research of invertebrate fauna using a range of sampling techniques recorded 183 species (58 mollusc species; 33 worm species; 24 ant species; 54 crustacean species; 12 fish species; and two other species) (Metcalfe, 2007). Crabs and other invertebrate fauna play an important role in the function and maintenance of mangrove habitats through their burrowing and soil bioturbation processes (this in turn facilitating seawater or tidal recharge of highly saline mangrove soils).

Peak invertebrate abundance is typically associated with the more seaward occurring *Sonneratia* mangrove zone (mapping unit 8), where deep unconsolidated muds and large, multi-trunked trees provide numerous habitat opportunities. While abundance and diversity generally decline in the more landward mangroves zones these areas also experience a marked seasonal variation.

Fish communities

A survey conducted in 1997 found 415 fish species in Darwin Harbour, including 31 new records for the NT (Larson and Williams, 1997). The most diverse group of fishes were gobies (70 species), cardinal fish (20 species) and pipefish (19 species). Fish species commonly harvested recreationally and by aboriginal fishers are found in the mangroves, 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).

Barramundi is a particularly important commercial and recreational fish species that spawns in river mouths where tides carry the eggs into supralittoral swamps. There are no such swamp systems in Darwin Harbour; the nearest one is located at Shoal Bay north of the harbour (DoR, 2009). There is very little suitable nursery habitat for barramundi in Darwin Harbour (URS, 2001).

15.2 Marine Communities of the Project Area

Most of the project area is surrounded by bare substrate. On the south side on EAW there are some moderate to high densities of sponge and soft coral beds and some scleractinian ("hard") coral communities around South Shell Island and Old Man Rock (Figure 15-1).

15.2.1 Rocky Shore Communities

There are few natural intertidal rocky shores in the vicinity of the Project area. However, the benthic communities on the artificial hard substrates (rock walls, wharf structures, piles, etc) provided by the existing East Arm Port and nearby structures (such as those associated with the old East Arm boat ramp) would be expected to be similar (in composition, abundance and diversity) to those inhabiting natural rocky shores elsewhere within Darwin Harbour (described in Section 15.1.1).

15.2.2 Hard Coral Communities

In the vicinity of the Project Area, hard coral communities have been recorded around South Shell Island (south of East Arm Point) and at Old Man Rock (URS, 2009; BMT WBM, 2010). Around South Shell Island, hard coral cover is highest (15-20%) at 0-1.5 m below LAT and declines with increasing depth (URS, 2009).

The community is comprised of at least 21 species, predominantly faviids with numerous *Turbinaria* colonies also present (URS, 2009). Coral cover at Old Man Rock is lower (<10% cover) and more limited in distribution than at South Shell Island (Figure 15-1); the community is predominantly comprised of faviids [primarily *Goniastrea*]) and *Goniopora* species (URS, 2009).

15.2.3 Filter Feeder Communities

A survey conducted in 2010 revealed moderate to high density sponge and soft coral beds in the areas surrounding South Shell Island and Old Man Rock and, to a lesser extent, low density sponge beds (Figure 15-1).

A survey conducted in 2008 by URS found that the dominant fauna on the lower slope (deeper than 1.5 m LAT) surrounding South Shell Island were numerous sponges, soft corals (including gorgonians [sea fans and sea whips]), crinoids (feather stars) and hydroids (URS, 2009). Other sites surveyed by divers and remote operated vehicles (ROV) in East Arm revealed a moderate to low diversity of benthos, with the exception of the south side of Old Man Rock and at Walker Shoal which had numerous soft corals and a high diversity of sponge species.

15.2.4 Macroalgae and Seagrasses

No substantial macroalgae beds, and no seagrasses, were recorded within the vicinity of the Project area by BMT WBM (2010).

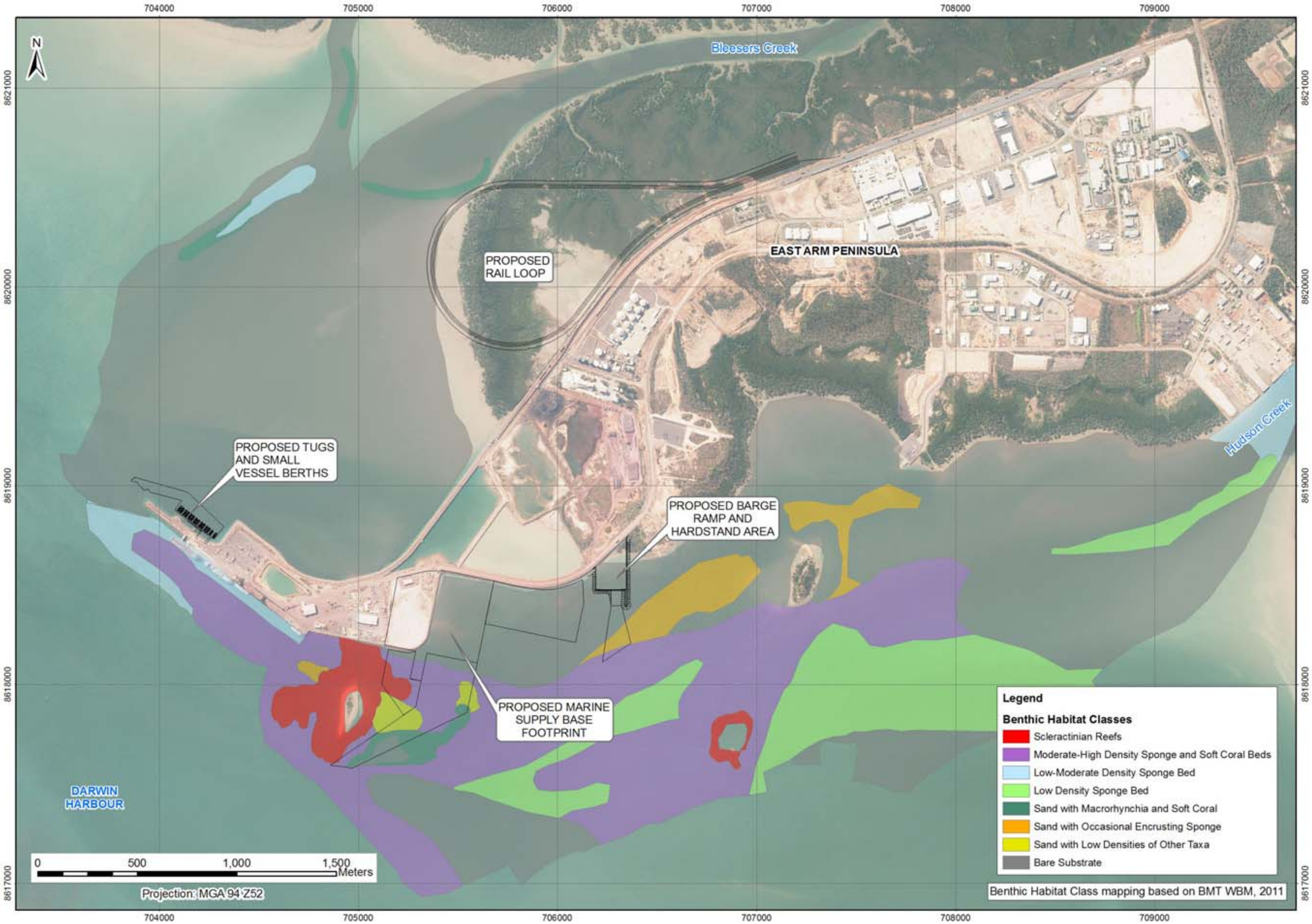

Figure 15-1 Benthic Habitat Classes Surrounding Eaw

15.2.5 Soft sediment communities

Whilst the benthic infauna communities of the soft sediment areas (seaward of the mangroves) within the Project area have not been surveyed, they could be expected to be similar to those occurring in intertidal and shallow subtidal soft substrates elsewhere within the harbour (as described in Section 15.1.1). They could also be expected to have strong affinities with the communities on the southern side of East Arm, which URS (2009) found were dominated by amphipods (small shrimp-like crustaceans) and polychaete worms.

15.2.6 Mangrove Communities

The distribution of mangrove communities at East Arm and elsewhere in Darwin Harbour reflects differences in tidal level, tidal inundation frequency, tidal erosion and sedimentation, wave action and freshwater recharge (for hinterland fringing mangroves) that creates a variety of environmental conditions. Mangrove species tend to assemble in distinct communities which form a predictable pattern of zones or assemblages from landward to seaward. Mapping of Darwin Harbour mangroves undertaken by Brocklehurst and Edmeades (1996) recognised 11 mangrove zones.

The main mangrove communities occurring on the East Arm peninsula (i.e. between Bleesers Creek and Hudson Creek) are shown in Figure 15-2 and are described below:

- Salt flats (mapping unit 11): Salt flats are areas of either bare mud flat or may support areas of sparse samphire shrubland. Salt flats are located at higher elevations on the tidal flat and receive irregular tidal inundation, hence soil salinities are very high and mangrove growth is largely precluded.
- *Ceriops* low closed forests and dense shrublands (mapping units 4 & 5): *Ceriops australis* is the dominant species, often forming very extensive stands. *Avicennia marina* is a minor species within this zone, typically occurring as an emergent taller tree above the *Ceriops* shrubs/trees. Height varies from 3-6 m depending on salinity regime. Soils are mainly muds and muddy sands. This community occurs across much of the mid-high tidal flat area to the north of the railway corridor. The frequency of tidal inundation in this zone is at least weekly to fortnightly.
- *Rhizophora* Closed Forest (mapping unit 2): This community is also referred to as “Tidal Creek Forest” in the mapping, however, it also occurs on the western and southern side of East Arm areas where no tidal creeks occur. In this case the *Rhizophora* zone occurs as shore parallel band between the *Ceriops* and *Sonneratia* zones. The dominant species is *Rhizophora stylosa,* which typically forms a closed canopy forest 6-10 m in height. Soils are waterlogged due to daily tidal inundation of the root structured muds.
- *Sonneratia* Woodland (mapping unit 8): This is the seaward most mangrove zone occurring along the harbour shoreline. *Sonneratia alba* is the dominant species typically occurring as large widely spaced trees in an open woodland community. Areas of bare mudflat, devoid of vegetation, are common between the large trees and sediments are unconsolidated marine muds.

The salinity of the groundwater and soil water on tidal flats and the adjoining hinterland is an important mechanism which regulates mangrove populations (Semeniuk, 1985). Soil water and groundwater salinity are closely linked to stratigraphy, substrate, recharge mechanisms and evapo-transpiration. The shallow groundwater bodies across the typical mangrove zones each have their own range of salinity and internal gradients of salinity and chemical composition due to the relative influence of seawater recharge, freshwater recharge and evaporation.

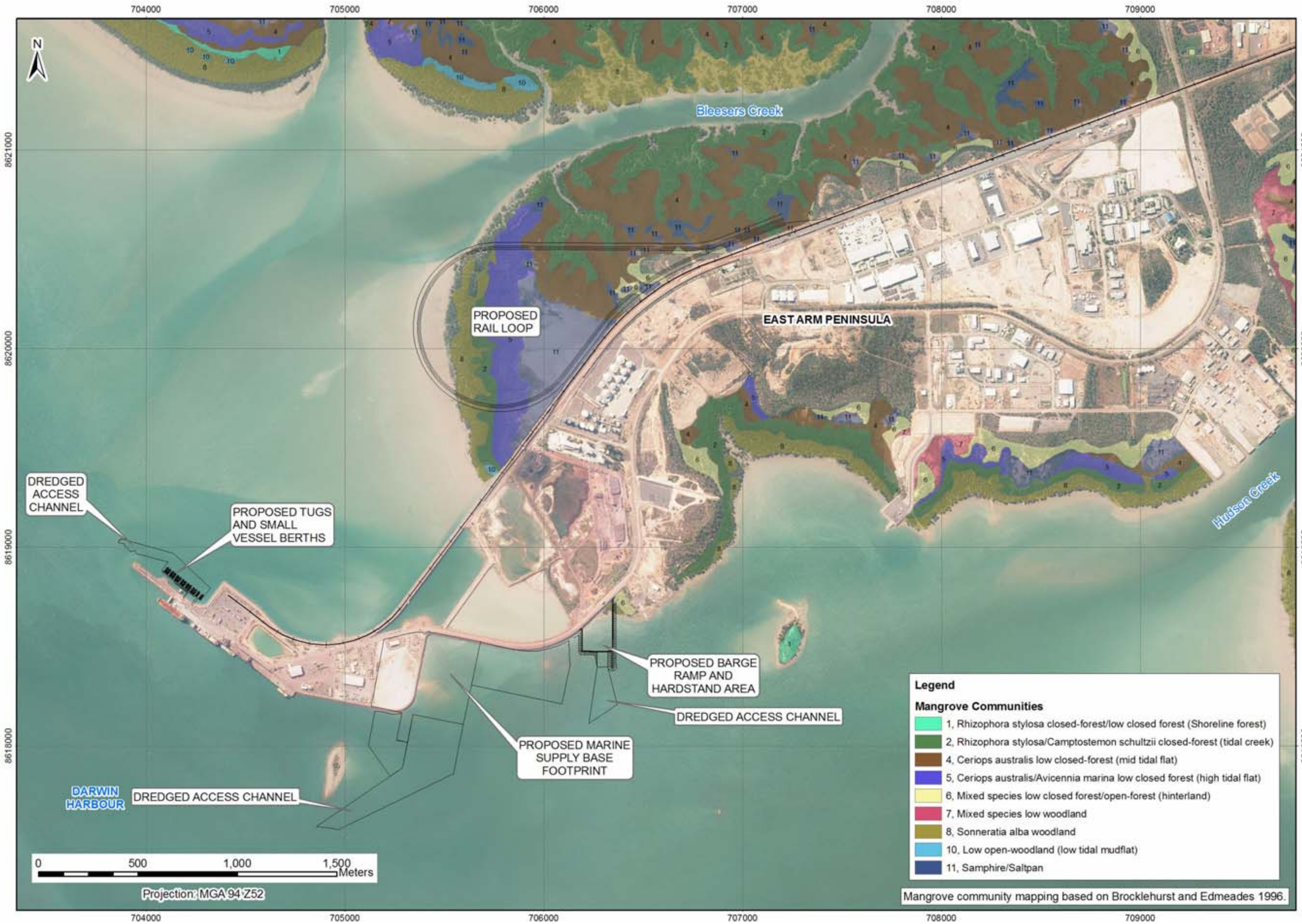

Figure 15-2 Mangrove Communities of East Arm Peninsula

Northern Territory Government

The disposition of aquifers and aquatards / aquacludes, and the processes of recharge, groundwater migration and evaporation results in a gradient of increasing hypersalinity across the mangrove zones (i.e. from the seaward to the more landward zones). In many areas of Darwin Harbour the salinity gradient described above is further complicated by a narrow zone of mixing between freshwater from terrestrial sources and the tidal flat (hypersaline) groundwater at the hinterland mangrove fringe where a narrow but diverse assemblage of mangroves occurs.

Mangroves form a valuable part of the marine ecosystem by producing large amounts of organic matter and nutrients that are utilised by animals such as crustaceans and fish. Many fish and prawns, including species significant to recreational and commercial fisheries, utilise mangroves as spawning grounds and nursery habitat (WMB, 2005).

Most mangrove tracts surrounding Darwin Harbour are zoned for “conservation” under the NT Planning Scheme (AECOM, 2009), recognising the biodiversity value of this vegetation community, and are classified as “significant vegetation” under NT clearing guidelines. However, the mangroves in the EAW Project area are within the EAW Area Development Zone and are not zoned for conservation.

15.2.7 Fish

URS (2009) considered pelagic fish life within East Arm to be moderate to abundant relative to other areas surveyed within Darwin Harbour. The following species were noted: *Protonibea diacanthus* (jewfish), *Platycephalus* sp. (flathead), *Synanceja verrucosa* (stonefish), Urolophidae (rays), as well as a number of sharks. Surgeon fish (Acanthuridae) and butterfly fish (Chaetodontidae) were noted at Old Man Rock (URS, 2009).

15.3 Protected Species in Darwin Harbour

Certain species within Darwin Harbour are protected under the following legislation and conventions:

- The Commonwealth EBPC Act
- TPWC Act
- The International Union for Conservation of Nature (IUCN)
- The Bonn Convention
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The EPBC Act provides a legal framework to protect and manage nationally and internationally threatened plants and animals. The EPBC Act also on species listed under international treaties and conventions. The Biodiversity Conservation Unit of NRETAS is responsible (under section 29 of the TPWC Act) for administering the NT Threatened Species List and for assessing and classifying the conservation status of all wildlife species occurring in the NT.

The IUCN Red List of Threatened Species, CITES and the Bonn Convention include marine animals that are considered to be under threat of extinction. The Bonn Convention is a convention on Migratory Species. Protected species that may be found in the vicinity of East Arm are listed in Table 15-1.

Table 15-1 Endangered or Vulnerable Species that may be Present Near or Within East Arm

Scientific name	Common name	Commonwealth	Northern Territory	IUCN	Bonn Convention	CITES
Cetaceans: Whales						
Megaptera novaeangliae	Humpback whale	V	-	LC	I	I
Reptiles						
Caretta caretta	Loggerhead turtle	E	E	E	I	I
Chelonia mydas	Green turtle	V	-	E	I	I
Dermochelys coriacea	Leatherback turtle	E	V	CE	I	I
Eretmochelys imbricata	Hawksbill turtle	V	-	CE	I	I
Lepidochelys olivacea	Pacific Ridley turtle	E	-	V	I	I
Natator depressus	Flatback turtle	V	-	DD	-	I
Cartilaginous Fish: Sharks						
Pristis clavata	Dwarf sawfish	V	V	CE	-	-
Pristis microdon	Freshwater sawfish	V	V	CE	-	II
Pristis zijsron	Green sawfish	V	V	CE	-	-
Rhincodon typus	Whale shark	V	-	V	II	II

V: Vulnerable, E: Endangered, LC: Least Concern, CE: Critically Endangered, DD: data deficient, -: not listed, I: listed under appendix I, II: Listed under Appendix II.

The known distribution of the species listed in Table 15-1 is as follows:

- Humpback whales: Migrates to northern Australia from June to August but rarely ventures as far northeast as the NT
- Turtles: Green, hawksbill and flatback turtles are seen foraging for food in Darwin Harbour. There are no known turtle nesting sites in Darwin Harbour as the mangroves and mudflats do not provide suitable nesting grounds. Other turtle species (Ridley and loggerhead) are thought to be infrequent users of Darwin Harbour. Leatherback turtles are typically oceanic and unlikely to occur within the harbour (URS, 2004)
- Sawfish: Dwarf sawfish, freshwater sawfish and green sawfish have not been recorded in Darwin Harbour.
- Whale shark: This species is not known to occur within Darwin Harbour.

In addition to the species in Table 15-1, several other species are listed as migratory species under the EPBC Act (Table 15-2).

Three coastal dolphins, the Australian snubfin (*Orcaella heinsohni*), the Indo-Pacific humpback (*Sousa chinensis*) and the Indo-Pacific bottlenose (*Tursiops aduncus*) are the most common cetaceans in Darwin Harbour (Palmer, 2008). The false killer whale (*Pseudorca crassidensis*) has also been recorded in the harbour (Palmer et al., 2009). Dugongs have been observed in Darwin Harbour south of the Middle Arm Peninsula and are thought to feed on macroalgae.

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Additional species of dolphins are listed under the EPBC Act: Common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), Spotted dolphin (*Stenella attenuata*), Bottlenose Dolphin (*Tursiops truncatus*) as all cetaceans are protected under this act.

Table 15-2 Migratory Marine Mammals, as Listed under the EPBC Act, that may be Present Near or Within East Arm

Scientific name	Common name	Conservation status			
		EPBC Act 1999 (Cwlth)	IUCN Red List	Bonn Convention	TPWC Act (NT)
Dugong dugon	Dugong	Migratory	-	-	-
Balaenoptera edeni	Bryde's whale	Migratory	DD	II	-
Megaptera novaeangliae	Humpback whale	Migratory	LC	I	NoT
Orcaella heinsohni	Australian snubfin dolphin	Migratory	V	I	-
Orcinus orca	Killer whale	Migratory	DD	II	-
Sousa chinensis	Indo-Pacific humpback dolphin	Migratory	NT	II	-
Tursiops aduncus	Spotted bottlenose dolphin	Migratory	DD	II	-

V: Vulnerable, E: Endangered, LC: Least Concern, CE: Critically Endangered, DD: data deficient, NT: Near Threatened, NoT: Not Threatened, -: not listed, I: listed under appendix I, II: Listed under Appendix II.

Dugongs have been observed in Darwin Harbour, including at Channel Island in Middle Arm, where they were thought to be feeding on macroalgae (Whiting, 2002). Dugongs could potentially utilise algal communities within East Arm (such as those around Old Man Rock) as a food source.

Bryde's whales and killer whales are not known to occur within Darwin Harbour, though pods of false killer whales (*Pseudorca crassidensis*) are known to visit the harbour (Palmer et al., 2009).

Contemporary knowledge of the taxonomy, distribution, microhabitats, residency and site fidelity of the three species of coastal dolphins is presented in INPEX Browse (2011). Recent surveys (January-March 2011) commissioned by INPEX showed that:

- The density of snubfin dolphins (*Orcaella heinsohni*) observed in the western parts of Darwin Harbour was substantially higher than that observed near East Arm and Blaydin Point over the two year period 2008 to 2010 (Palmer 2010a, Palmer 2010b). This is consistent with observations reported by Palmer (2010a) indicating that the highest abundance was in the north western parts of the Harbour.
- The density of Indo-Pacific humpback dolphins (*Sousa chinensis*) observed in the western parts of the Harbour was comparable to that observed near East Arm and Blaydin Point over the two year period from 2008 to 2010 (Palmer 2010a, 2010b).
- The density of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) observed in the western parts of the Harbour is comparable to that observed in the eastern parts of the Harbour but less than that observed in the northern parts of the Harbour.

Other species of dolphin listed under the EPBC Act that may occur in Darwin Harbour are the common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), spotted dolphin (*Stenella attenuata*) and bottlenose dolphin (*Tursiops truncatus*).

15.4 Marine Pests

Marine pests are marine species that have been introduced into a new environment, either inadvertently or deliberately, that cause considerable environmental or economic damage in their new area. Fortunately, only a small proportion of introduced species become pests.

Of the more than 250 introduced marine species known to now be in Australia, only about a dozen are regarded as pests. However, it is very difficult to predict which species will become pests. A species may appear to be innocuous when introduced into one location, but in another environment the same species can become a pest. Once a species becomes established in a new marine environment it can increase rapidly and be impossible to eradicate. It is critical to prevent their arrival or, failing that, attempt to eradicate them as soon as possible.

Introduced marine pests can substantially alter the structure of local ecosystems, threaten commercial fisheries, introduce diseases into other marine species and even humans, and foul industrial structures and piping. While the financial costs of introduced marine pests have not been determined, they can be substantial (Hayes et al., 2005; Wells et al., 2008).

Unlike terrestrial environments, marine pests inhabit areas that are largely unseen by the casual observer. It is generally considered that the number of marine pests in Australia is increasing. However, in recent decades there has been a growing number of people scuba diving and snorkelling in the marine world. Increasing public awareness of the damage caused by marine pests encourages people to look for them.

It is also true that there has been a substantial enlargement of the vectors that can transport marine pests. Any vessel moving through the oceans from one area to another can potentially translocate a marine pest into a new region. Movements by shipping and pleasure craft have grown dramatically in recent years, particularly in northern Australia, where the mining and petrochemical booms have brought many vessels into northern waters as new facilities have been constructed and become operational.

While there have been a number of outbreaks of marine pests in Australian waters, one northern waters species has received considerable public attention: the black striped mussel *Mytilopsis sallei*.

A dry season survey for marine pests was conducted in Darwin Harbour in August 1998 by the CSIRO Centre for Research Into Marine Pests (CRIMP) and the Museums and Art Galleries of the Northern Territory (MAGNT); no suspect species were found. The survey was repeated only seven months later, in March 1999, just after the end of the wet season. Massive populations of the Caribbean black striped mussel, *Mytilopsis sallei*, were found in the Cullen Bay Marina.

The mussel occurred on virtually every hard surface in the marina, with densities reaching almost 24,000/m^2. The largest animals were mature and appeared to have gone through two complete generations. Surveys taken elsewhere in Darwin Harbour found populations of mussels in Tipperary Waters Marina and Frances Bay Marina, on the hulls of three yachts that had been in Cullen Bay and on a bamboo raft that had been brought to Darwin from Indonesia. An environmental emergency was declared.

The bamboo raft was taken ashore and burned. Because of the 8 m tides that occur in Darwin, all of the marinas have a lock at their entrance that allows boats to enter and leave at any stage of the tide. The locks also had the advantage of allowing the marinas to be completely sealed off from the open waters of Darwin Harbour. The three yachts were returned to Cullen Bay and boats in the marinas were not allowed to leave. Substantial quantities of chlorine and copper sulphate were added to the marinas and the mussels were monitored until all had died.

Boats that had been in the three marinas prior to the discovery of the black striped mussels were examined wherever they were located, but no further infestations were found (Russell & Hewitt, 2000; Willan et al., 2000). The elimination of the black striped mussel in Darwin was successful only because the animal had not colonised the open areas of Darwin Harbour; if it had become established in the harbour, it is unlikely that it could have been eliminated.

The Asian green mussel, *Perna viridis*, is a hardy species that is widely farmed in south-east Asia and is one of the key aquaculture species in the world. Unfortunately, the Asian green mussel is also an invasive species that readily develops large populations where it has been introduced.

In another serious marine pest incident, the illegal foreign fishing vessel *MV Wing Sang 108* was apprehended illegally fishing in Australian waters. The boat was taken to Cairns where it was anchored for a year in Trinity Inlet, during which it became heavily fouled with the Caribbean tubeworm *Hydroides sanctaecrucis*. When it was cleaned in August 2001, the hull of the MV Wing Sang 108 was found to have dense clusters of *P. viridis*.

A survey was conducted of Trinity Inlet and a small number of *P. viridis* were found (Neil et al., 2005). It is believed that a small breeding population of Asian green mussel was established in Cairns (Stafford, Willan and Neil, 2007), that may have since died out. Asian green mussels can readily be introduced into Darwin Harbour on illegal foreign fishing vessels or on vessels coming from south-east Asian ports.

The great majority of marine introductions worldwide have been through vessel movements, primarily international shipping. The two main vectors of marine pests in commercial vessels are ballast water and biofouling, both of which are discussed below.

15.4.1 Ballast Water

Ships are designed to move through the water at a particular depth. If they are lightly loaded the vessel becomes hard to steer, subject to windage, fuel consumption rises, there is increased risk of an accident, etc. Many large commercial vessels coming to northern Australia, such as bulk carriers and LNG tankers, are empty on their voyage to Australia, but are fully laden and low in the water when they return to their port of origin. The solution is simple, but effective. Large ballast tanks are constructed in the vessel.

When the cargo is discharged its weight is replaced with ballast water that maintains the proper position of the ship. While freshwater is occasionally used, most ballast water is seawater. Smaller vessels and nontrading vessels such as naval vessels, research ships, cruise liners, etc do not carry ballast water, but have small amounts of trim water which serves essentially the same purpose.

Large bulk carriers may each carry tens of thousands of tonnes of ballast water. Huge amounts of ballast water are imported into Australia every year. For example, a recent report showed that over

123 Mt of ballast water were discharged in Western Australian ports in the year 2006 alone, nearly 117 Mt of which were from overseas (McDonald, 2008).

While the use of ballast water provides a simple and effective solution to the problem of maintaining the vessel's position in the water, it also carries inherent risks for introducing marine pests into new locations. Unfortunately, when the ballast water is taken on board it includes all of the organisms living in the water, sediment particles, etc. Some of the organisms are adults and larval stages of organisms that live throughout their life cycle in the water column itself. Others are larval stages of plants and animals that are benthic as adults.

Many of these species are able to thrive in the dark environment of the ballast tanks, in the water itself or by settling on the sides of the tanks. Sediment brought in with the water settles to the bottom of the tanks, forming a muddy bottom which can be colonised by species that typically inhabit mud. There are few large predators in the ballast water tanks.

When the ballast water is discharged, the entrained plants and animals are introduced into the new area. If the required environmental conditions are present they will survive and establish new populations. Species such as the North Pacific sea star are thought to have been introduced into Australia through ballast water. Ballast water was originally thought to be the predominant source of introduced marine pests in Australia, but in recent years it has been estimated that three-quarters of the marine pests have been introduced through biofouling.

15.4.2 Biofouling

When an object is placed into the sea, organisms immediately begin to settle and grow on it, a process known as biofouling. The amount of material growing on the surface rapidly increases, and the biofouling community growing on the object changes. Three phases of biofouling are recognised:

- Primary - Initially biochemical and bacterial conditioning occurs on the newly exposed surface. A thin layer of microalgae then develops, with filamentous algae growing to a length of 5 mm.
- Secondary - In the second phase animals including barnacles, bryozoans, hydroids and worms begin to settle and grow on the surface. As the secondary fouling becomes thicker, small, mobile species such as amphipods begin to occur.
- Tertiary - By the time the tertiary stage is reached, a fully developed community with sponges, ascidians, bivalve molluscs (mussels, oysters, and clams), sea anemones, worms, marine algae, etc. has become established. The biofouling community has a three dimensional structure, with numerous nooks and crannies where mobile faunal species can seek shelter. These include starfish, gastropods, crustaceans, bryozoans and tunicates. Diversity increases significantly as the enlarged number of habitats allows for an increasing number of species to be present, further increasing the number of available habitats.

Unlike ballast water, biofouling develops on vessels and structures of all sizes. The distribution of biofouling on a single vessel is not uniform. The smooth, open surfaces of the hull are subjected to the greatest water flow when the vessel is underway, so it is more difficult for biofouling species to obtain and maintain purchase there. Niche areas where there are nooks and crannies have less water flow, and are easier for species to adhere.

Beginning in the late 1960s, tributyltin came into widespread use as an antifoulant to retard the development of biofouling. The chemical was added to boat paints and was released slowly to maintain its effectiveness. Unfortunately, tributyltin had to be extremely toxic to be effective in retarding the development of biofouling. This very characteristic meant that the chemical also caused environmental damage in ports and harbours. It is currently being replaced by copper based antifouling chemicals.

The biofouling risk presented by different classes of vessels differs substantially. Mobile infrastructures such as dredges, oil rigs, drydocks, etc are considered to be of high risk for the introduction of marine pests for a number of reasons, in that they:

- Undertake a broad range of activities.
- Often travel for considerable distances between contracts.
- Remain for extended periods in ports, where marine pests are concentrated.
- Are slow moving or stationary.
- Equipment may routinely be left in the water for 24 hours or more.
- Are in close contact with the bottom (Kinloch, Summerson, and Curran, 2003).

In contrast, trading vessels do not have the above characteristics. These ships move from the home port to Darwin rapidly through the open sea. The time they spend in Darwin is minimal as they load another cargo and depart on the delivery run. Trading vessels are not in close contact with the bottom, and are generally well maintained, with intact antifouling coating.

These factors mean that the risk of introducing a marine pest will be greater in the construction phase of the project than in the operational phase.

15.5 Potential Impacts

The environmental assessment presented in this section includes discussion of potential impacts of the project in a broad regional context, including MNES as defined in the EPBC Act. MNES relevant to the EAW development include:

- Listed threatened species and ecological communities.
- Migratory species protected under international agreements.

To minimise environmental impacts of the Project, management controls are described that will be implemented by NTG to mitigate possible negative impacts from Project activities.

To determine the “Residual risk” after the management controls are implemented, an assessment of the various potential impacts was undertaken (refer to Chapter 25). Summary tables are presented that describe the activity, management controls and mitigating factors, and the resulting residual risk (including consequences, likelihood and risk rating).

The risk assessment was undertaken in consideration of the sensitive environmental receptors in the region, including the marine benthic biota and macrofauna that occurs in the area of EAW. As the wharf is near the cities of Darwin and Palmerston, and is a key infrastructure facility in the region, the local community is also regarded as a key sensitive receptor in some aspects of the proposed development. Other impacts to the community such as potential impacts to commercial and recreational fishing are described in Chapter 23.

Management controls will be implemented to ensure the potential environmental impacts of the proposed development are minimised. A variety of monitoring programs will be developed to ensure that DLP is able to determine the effectiveness of the management controls.

15.5.1 Alteration of Habitat

Construction of Project facilities will alter the marine habitats in the nearshore area of the EAW through:

- Land reclamation.
- Creation of artificial hard substrate habitats.
- Dredging to create berthing pockets and navigational channels.

Land Reclamation

Land reclamation associated with the construction of the rail loop, MSB and barge ramp hardstand area will result in the direct loss or disturbance to intertidal habitats including mangrove areas, salt flats and low tidal mudflats seaward of the mangrove zone. Figure 15-3 shows where these areas of potential disturbance may occur.

Mangroves

Mangroves will be impacted directly (by removal) and indirectly (e.g. through changes to tidal exchange). The maximum extent of potential mangrove loss from the project footprint, as shown in Figure 15-3 is 74 ha, this being comprised of 22 ha from the placement of the rail corridor and loop (i.e. direct clearing of mangroves) and 52 ha from the impoundment of mangrove habitat within the rail loop (potential indirect loss). Based on experience with the existing development, it is expected that mangroves will probably recolonise the rail loop shoreline within a few years.

Case studies (Gordon, 1988) involving the placement of infrastructure such as causeways, levees and roads across tidal creeks indicate that the changes to tidal flows arising from such structures may result in the following impacts. It is noted, however, that current good design practice avoids or mitigates these potential impacts as much as is practicable:

- Localised erosion of creek banks in the immediate vicinity of the culverts.
- Reduction in tidal flushing and the extent of tidal flat inundation in areas upstream from a restriction point such as a bund or causeway. Tidal inundation is the dominant recharge mechanism responsible for maintaining the groundwater / soilwater conditions required for mangrove growth and survival (Galloway, 1982; Gordon, 1987) and modifications to tidal wetting and drying regimes can potentially impact mangroves. A decrease in tidal inundation may cause increasing groundwater / soilwater salinities and this could result in loss of mangroves in marginal fringing environments which have high salinities under natural conditions. Culverts and other structures can mitigate these potential impacts.
- Impoundment of water at higher than natural levels, which can result in mangrove decline and death due to sustained inundation of pneumatophores (mangrove aerial roots) and a decline in water quality (i.e. ponding effects). Again, culverts and other structures can mitigate these potential impacts.

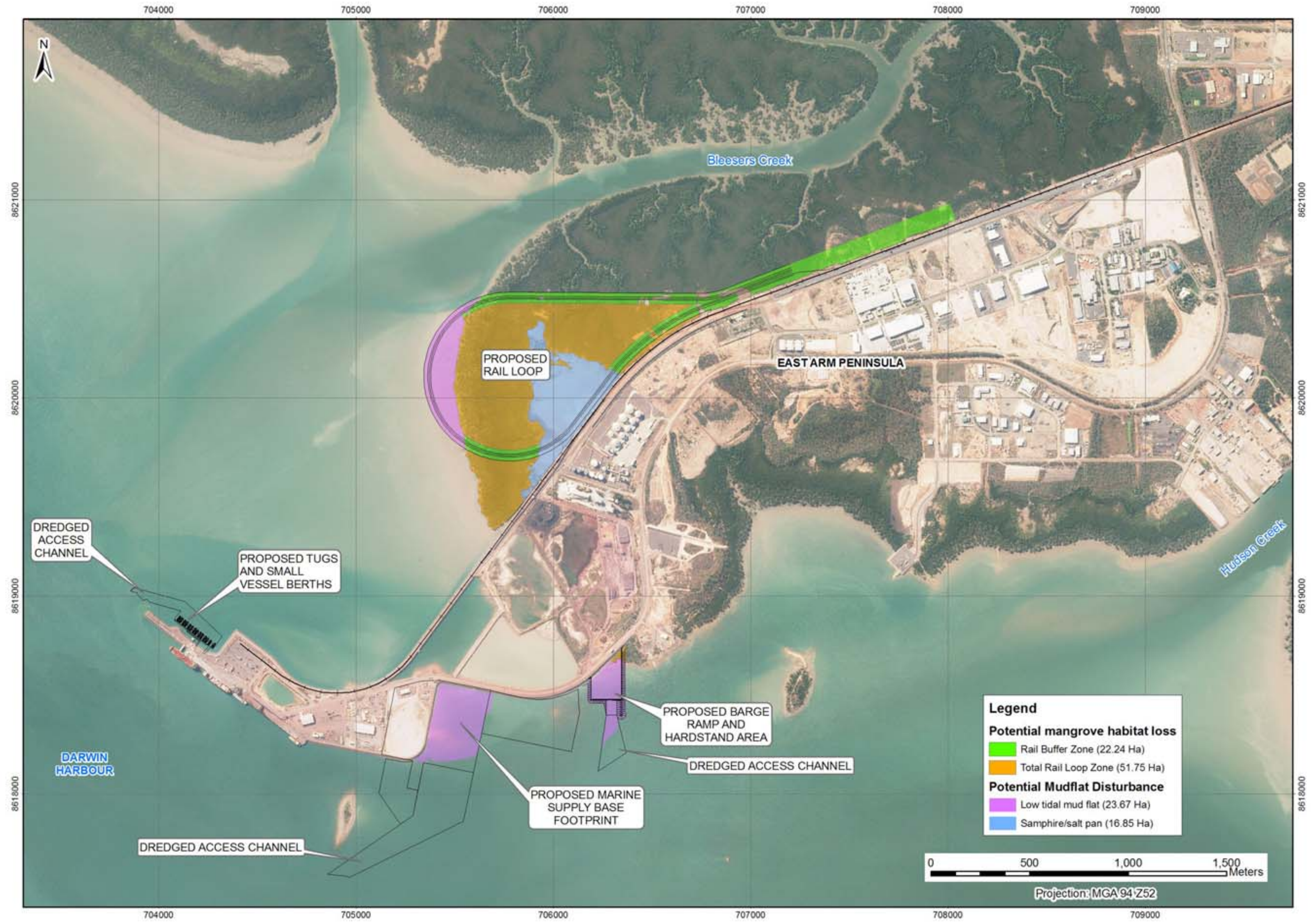

Figure 15-3 Potential Mangrove and Low Tidal Mud Flat Loss and Disturbance

The placement of large volumes of fill (sediment) and/or water onto tidal mudflats also has the potential to produce hydraulic loading effects, resulting in changes to mangrove areas immediately adjacent to the outer embankments containing such material. Examples of this effect are:

- The placement of large volumes of fill onto a tidal flat resulted in the lateral displacement of the existing mangrove muds and the subsequent development of mudwaves parallel to the toe of the fill area for distances between 10 and 30 m seaward of the fill area toe line. The mudwaves caused physical and biological changes and resulted in mangrove stress and mortality (URS, 2004). However, based on experience elsewhere in the Harbour, it is expected that ultimately mangroves will probably recolonise these areas.
- The containment of large volumes of water or dredge spoil/slurrries in ponds constructed within some tidal flat settings can establish a hydrostatic head between the pond water level and the shallow groundwater level in mangrove areas adjacent to the pond levee. The differential displaces the highly saline groundwater of the tidal flats and elevates water tables, creating a zone of impact on adjacent mangrove habitats (i.e. salinity increase and waterlogging effect). Monitoring of shallow groundwater conditions has shown initial increases in salinities and elevations of water tables within the impact zones (Gordon, LeProvost and Bradley, 1995; LDM, 1998; URS Dames & Moore, 2000).

The mangrove tracts around the Darwin harbour shoreline are extensive and the potential 74 ha mangrove loss associated with the project represents 0.3% of the 27,000 ha of mangroves that currently exist. In this context, the mangrove loss could not be considered as having a potentially significant impact upon mangrove ecosystems at the broader regional scale. It is also noted that, based on experience with the existing development, it is expected that mangroves will probably recolonise the fringes of reclaimed areas within a few years.

Mud Flats

Approximately 24 ha of low tidal mud flat habitat will be either reclaimed or substantially disturbed during construction of the project. In Darwin Harbour shorebirds forage on the extensive areas of low tidal mud and sand flats (when exposed during low tides) that are located seaward of the mangrove shoreline. These areas can provide an abundant source of intertidal invertebrate fauna for shorebirds to feed on.

In the context of the extensive areas of tidal mud flats in the Darwin Harbour region, the area (24 ha) to be impacted by the EAW project is very small and hence it is unlikely to present any significant threat to shorebird populations in Darwin Harbour.

Surveys of shorebirds along the NT coast included a survey block that extended from Fog Bay to Point Stevens, including Bynoe Harbour and the islands to its west, Darwin Harbour and the Vernon Islands (Chatto, 2003). Shorebirds were found to be widely distributed and due to the coast being thickly lined with mangroves, overall densities of shorebirds were not generally high. The EAW area was not recognised as an important area for shorebirds or an area that had significant populations of shorebirds by comparison with other sites in the survey block (Chatto, 2003).

15.5.2 Artificial Habitats

Jetty structures and rock walls constructed for the Project will represent a very small incremental increase in the area of hard substrate present within Darwin Harbour, providing additional habitats for species adapted to living in them. Over time, a fouling community will develop on the substrate; this is likely to be similar to that present on other artificial habitats in Darwin Harbour, particularly the existing structures at EAW, and on natural rocky shore substrates.

The physical structures, and the developing fouling communities thereon, will provide additional three-dimensional structures to which species from higher trophic levels (e.g. crustaceans, fish) are likely to be attracted, either as refuges from predation or as food resources. As the biodiversity of hard substrates is typically higher than that of soft substrates in similar environmental settings, the new artificial habitats are likely to lead to a localised increase in biodiversity, which is unlikely to be of significance on a harbour or regional scale.

15.5.3 Dredging

The marine environmental impacts of the EAW Project are concentrated in the area near the existing wharf, where construction and operational activities will be concentrated. Accordingly, this section concentrates on this area of primary impact. A secondary impact area will occur offshore, where dredge spoil is disposed; this is addressed in Section 15.5.5.

Impacts of dredging upon the marine environment will comprise direct impacts (i.e. physical removal by the dredging process) and indirect impacts (e.g. impacts from light attenuation by turbid plumes, settlement of suspended sediments on areas outside of the dredging footprint). The areas of primary impact are shown in Figure 15-3.

The potential impacts of dredging upon biodiversity and trophic structure within Darwin Harbour are discussed in detail by INPEX Browse (2011). It should be recognised that the volume of dredging proposed for the EAW Project is an order of magnitude less than that proposed by INPEX.

Predictive Modelling

URS has undertaken sediment fate modelling to predict the dispersal of turbid plumes from dredging activities, and to predict the areas in which suspended sediments will accumulate. The results of the modelling are discussed in Section 8.2, and in more detail in **Appendix D**.

Potential Impacts on Mangroves

Key adaptations of mangrove trees to the intertidal environment are aerial root systems that allow for root respiration in the typically anaerobic muds. These occur as a network of cable roots (extending out from the base of the tree) and vertical roots (pneumatophores) in *Sonneratia* and *Avicennia* species, and in the form of stilt roots or buttressed trunks in *Rhizophora* and *Ceriops* species.

While mangroves are known to promote sedimentation due to their high stem density and complex aerial root structures, the deposition of sediment within mangrove areas has the potential to cause impacts to mangroves if the depositing material accumulates in excess of natural sedimentation rates and to sufficient depths to bury the aerial root system. Sedimentation impacts within mangroves can potentially arise from:

- Turbid plumes related to dredging operations and the discharge of tailwater.
- Localised sedimentation/erosion effects in mangroves adjacent to tailwater discharge points.
- Over-topping of settlement ponds, bund wall failure or pipeline rupture and any consequent uncontrolled released of material (silts, slurries, etc.) into mangrove areas.

- Erosion from non-vegetated surfaces or uncontained areas (e.g. levees, access roads, laydown areas) and subsequent deposition of material into adjacent mangrove areas.

A review of case studies of impacts from sediment burial of mangroves in Australia (Ellison, 1998) provides examples of mangrove degradation and/or death from depths between 5 and 200 cm. The response of different mangrove species to root burial does not appear to be standardised and is likely to be a function of root architecture, tidal range, and sediment composition and grain size.

While Ellison (1998) noted that there is insufficient data available to establish specific tolerances, its considered that sedimentation levels of between 5-10 cm may cause deterioration in mangrove health in those species with pneumatophore root structures (i.e. *Sonneratia* and *Avicennia* species). *Rhizophora* trees can be expected to tolerate higher levels of sedimentation.

A considerable area of uncertainty exists regarding the rates of sedimentation that cause mangrove impacts and it should be noted that many of the sediment burial events described in Ellison (1998) resulted from instances of rapid sediment deposition (e.g. floods, cyclones or short-term human disturbance) and hence may not necessarily be applicable to more gradual rates of sedimentation such those likely from dredging programmes.

Modelling of dredging related sedimentation (Section 8.2.2, and **Appendix E**) has predicted that up to 1.0-5.0 mm of sediment will be deposited to the north of the EAW, and less than 1.0 mm elsewhere, over the duration of the dredging program. The areas in which deposition is primarily anticipated to occur are those immediately to the east of the barge ramp and hardstand, and those within the Hudson Creek mangrove system. It should be noted that this sediment will be deposited over a period in excess of 100 days, so daily accretion rates are likely to be within the range typically experienced by the mangroves under natural conditions.

Potential Impacts on Hard Coral Communities

In a project such as that at EAW, sedimentation and turbidity are the major factors that can potentially result in the loss of scleractinian (hard) corals (Cortés and Risk, 1985; Hodgson, 1990; Pastorok and Bilyard, 1985; Rogers, 1983).

Sediments become suspended in the water column during dredging. As the particles settle to the bottom, they can smother corals living on the seabed if they are unable to remove the sediment quickly enough. The increased turbidity of the water reduces light available to the corals, causing a reduction of photosynthesis within the coral tissues (Great Barrier Marine Park Authority, undated).

Excessive turbidity and sedimentation can reduce growth and calcification rates of the corals. If this continues long enough at sufficiently high levels it can cause coral bleaching and even coral mortality (Rogers, 1983; Wesseling et al., 1999; Torres and Morelock, 2002). At lower levels of sedimentation, accumulation of sediment on the coral surface or bacterial infections can cause necrosis of coral tissues. In addition increased friction on the surface of the polyps can cause abrasion (Rogers, 1983; Hodgson, 1990; Wesseling et al., 1999).

Corals have a natural ability to remove sediment from their surface by sloughing off mucus, which traps the sediment particles and removes them from the corals (Philipp and Fabricius, 2003). Different species have varying capabilities for removing sediment; species living in Darwin Harbour are those that necessarily have a greater ability to remove sediments. However, as producing the required mucus is metabolically expensive, prolonged exposure to increased turbidity can weaken or even kill the corals (Philipp and Fabricius, 2003).

Coral communities may not recover if a mass mortality occurs in an area, particularly if the cause of the mortality also causes a decline in settlement during the next reproductive season (Babcock and Smith, 2002; Birrell, McCook and Willis, 2005). When the corals are lost, the community may shift to become dominated by macroalgae or filter feeders (Gilmour et al 2006).

The coral species living in Darwin Harbour are adapted to living in an environment with high water turbidity, which peaks every two weeks within the spring tidal cycle (URS 2011). In addition, the presence of corals in the harbour indicates that they are able to survive (or recover from) the increased turbidity associated with cyclones and other high rainfall events that periodically occur in Darwin. The extent to which corals are subjected to these stresses varies with a variety of factors, including their location and depth, and the various species have differing capabilities in surviving turbidity events. One key to coral survival in these natural turbidity events is that they are of relatively short duration.

Modelling of dredge plume dispersion from the EAW project (refer **Appendix E**) shows that maximum suspended sediment concentrations of up to 5 mg/L above background are predicted to occur across the South Shell Island coral community during dredging of the MSB (a period of approximately two months) and the tug & small vessel berths (six days). These concentrations, which will be temporary elevations as plumes pass over the coral communities, represent maximum incremental increases of 25% above the mean suspended sediment concentration reported by Drewry et al (2010) for the “mid-estuary” of Darwin Harbour (20 mg/L). Further, an additional SSC of 5 mg/L is below the tolerance limits determined by INPEX Browse (2011) for the South Shell Island coral community (10.5 mg/L in the dry season, 25.2 mg/L in the wet season).

The modelling predicts that no sediment deposition of greater than 0.1 mm in thickness will occur upon the South Shell Island coral community over the course of dredging (refer **Appendix E**). The majority of the sediments within the plumes generated by dredging will be of small particle size, which will only settle through the water column at periods of slack water, when tidal currents are sufficiently low. Hence, whilst the plumes will be carried across the coral community, the sediments will tend to settle from the water column either upstream (at high water) or downstream (at low water) of the community.

It is recognised that modelling did not include the mobilisation and deposition of coarse sediments. It is possible that during dredging of the approach channel to the MSB coarse sediments may smother some coral colonies within the South Shell Island coral community if dredging occurs in sufficiently close proximity during ebb tides. The only substantial coral mortality attributable to a recent (2004) dredging program in Mermaid Sound, Dampier, Western Australia, was due to smothering of coral colonies in close proximity to the dredge, rather than to light attenuation due to increased suspended sediment concentrations (Blakeway 2005).

In the event that hard corals within the South Shell Island coral community suffer mortality during the dredging program, it is considered likely that the affected areas will recolonise with hard corals over time, either through self-seeding from the surviving corals within the community, or via larvae from other communities within Darwin Harbour. If areas of the coral community are smothered by sediments, and these sediments are sufficiently stable despite the frequent strong tidal currents, then these areas are lilely to be colonised by soft bottom communities.

Potential Impacts on Filter Feeder Communities

Limited areas of seabed supporting filter feeder communities will be directly removed by dredging (refer **Appendix E**). After the completion of dredging, those areas of seabed that remain as exposed hard substrate are likely to be recolonised by filter feeder communities. In areas where the dredged surface is covered with soft sediment, soft bottom communities of infauna and epibenthic fauna will become established.

Modelling of dredge plume dispersion from the EAW project (refer **Appendix E**) shows that some of the filter feeder communities in the vicinity of the Project area are predicted to receive increased levels of suspended sediments of up to 5 mg/L. This represents a maximum incremental increase of 25% above the mean suspended sediment concentration reported by Drewry et al (2010) for the “mid-estuary” of Darwin Harbour (20 mg/L). Model outputs show a maximum predicted depth of sediment deposition of 1 mm within some of the filter feeder communities within East Arm, which would be expected to be too low to elicit an adverse response in all except the smallest encrusting species of sponges.

Whilst respiratory and feeding structures of filter feeding fauna could be clogged by increased sediment loads, at lower concentrations the fauna may benefit from the increased supply of food particles in the sediments released from the dredge. If mortality of filter feeders was to occur, it is considered most likely that they would re-establish over time through recruitment from surviving species either within East Arm or from farther afield.

Studies documenting recovery of filter feeder communities after impact are generally scarce. However, certain sponge species have been found to have a high capacity to adapt to changing and stressful conditions and recover quickly (Carballo 2006; Rützler; Duran & Piantoni 2007). This high recovery capacity is partly attributable to their primitive level of organisation, which bestows upon them a high adaptation potential. For example, some species have been reported to adapt to increased sedimentation by altering their morphology to minimise or prevent the settlement of sediment (Carballo 2006).

During the Pluto LNG Project in Western Australia, photographic monitoring of sponge coverage was undertaken in 2006 (before dredging commenced) and after the intensive dredging campaign in 2008, then again in 2009. Declines in sponge cover were noted after the initial intense dredging phase but considerable recovery of sponge density was evident in the later surveys. Recovery was predominantly a result of sponges clearing sediment loads which had obscured them in the 2008 survey, with some regrowth (or at least spatial extension) of sponges to near their original size (Department of State Development, 2010).

Any net changes in the distribution, abundance and diversity of filter feeder communities as a result of direct and indirect impacts from dredging are highly unlikely to be sufficiently large to substantially influence the trophic structure within Darwin Harbour.

Potential Impacts on Soft Bottom Communities

As for filter feeder communities, soft bottom communities will be exposed to potential direct impacts (physical removal) and indirect impacts (sedimentation) from dredging. The areas of soft bottom communities that will be removed by dredging are shown in Figure 15-2. Together, these areas represent a minor proportion of the area of similar habitat within East Arm.

The areas subject to sedimentation are shown in **Appendix E**. In most of the areas, sediment deposition is predicted to be less than 5 mm over the duration of the dredging program. It is considered that such deposition is probably within the same order of magnitude as that occurring naturally within East Arm during spring phases of the tidal cycle. Hence, motile epibenthic species are unlikely to be significantly impacted whilst infauna species (tubeworms, bivalve molluscs, etc.) are likely to have the capacity to maintain their connection with the sediment surface under such low deposition rates. This is supported by a review of literature on the effects of sediments on benthic invertebrate fauna (presented in INPEX Browse [2011]), which concluded that, although there is a high variability in response thresholds to burial, most species are able to cope with burial depths of greater than 10 cm, and many can tolerate 200 mm or more.

Areas of direct impact that are subsequently covered by sediment, and any areas in which sedimentation rates may be sufficiently high to lead to mortality of soft bottom fauna, will initially be populated by a relatively few colonising species, each of which may be present at relatively high densities. This may occur within days to weeks for mobile species. Sedentary species, such as tubeworms, will begin to arrive as settling larvae during the next spawning cycle. Over time animal diversity will increase in the soft sediments and a more complex community will be established. Such re-establishment of soft bottom communities has been demonstrated in studies from around the world (e.g. Evans et al. 1998; Newell, Seiderer and Hitchcock 1998; Ray 2000; WBM Oceanics Australia 2002; Dernie et al. 2003; Somerfield et al. 2006; Bolam et al. 2010).

The timeframe for recolonisation cannot be accurately predicted, as it will be influenced by factors such as the mobility and reproductive mechanisms utilised by individual species and the time required for the seabed to reach a stable condition. The communities that become established may differ in diversity, composition and abundance from those present prior to dredging. However, taking into consideration the likely duration of any impacts, and the vast areas of similar habitat within Darwin Harbour, it is considered highly improbable that these impacts could influence the trophic dynamics within East Arm or the broader harbour. Wilson (1998) monitored soft substrate fauna recolonisation in Botany Bay throughout a dredging program and found that dredging had altered some habitats, resulting in different faunal compositions. However, it was noted that functional relationships in an ecosystem can be preserved even if the species composition changes. This is also consistent with the findings of Metcalfe (2007), who found that invertebrate diversity and abundance in the mangrove communities in Darwin Harbour did not decline in response to moderate levels of anthropogenic disturbance.

Potential Impacts on Marine Mammals

Dolphins have well developed sight capabilities which are used effectively in predator avoidance and social interactions. As their eyes point towards the side rather than forward it is thought that they have a limited ability to catch prey by sight. However, this is compensated by well developed echo location capabilities, which are thought to be the primary method of prey location.

In any case, dolphins are frequently seen feeding in turbid areas where vision would be ineffective in locating prey (Mustoe, 2006). Examples of such feeding behaviour include the dolphins stirring up mud on the sea bottom to expose fish and crabs. Another example is dolphins feeding on bottom dwelling fish that have been exposed by the propeller wash of vessels.

Australian snubfin dolphins have frequently been observed feeding in turbid shallow areas near river mouths where the water is less than 20 m deep. Indo-Pacific dolphins are found in slightly deeper areas, including dredged channels (Parra, 2006). Both species forage in a variety of habitats, ranging from mangrove communities to seagrass beds, sandy bottom communities and open coastal areas with rocky shores and coral reefs (DSEWPC, 2011).

With the exception of seagrass beds, all of these habitats occur widely in Darwin Harbour, and there are extensive such habitats in the region outside the harbour. As the area to be affected by dredging for the EAW Project is only a small proportion of the total available habitat and the effects of dredging will be relatively short term, there is expected to be little effect on dolphin populations. In addition, the turbid plumes caused by the EAW dredging program may be utilised by dolphins for foraging.

Dugong feeding in Darwin Harbour is concentrated in areas such as the rocky reefs at Weed Reef, Channel Island and sea grass beds, none of which are near EAW; dugong feeding is therefore not expected to be affected by the dredging program.

Potential Impacts on Marine Reptiles

Green, hawksbill and flatback turtles are the most common species of turtles in Darwin Harbour. While each species has its particular preferences, they all use wide areas of the harbour for foraging, but there are no known major nesting areas.

In particular, flatback turtles feed in shallow, turbid waters (DSEWPC, 2011) and are unlikely to be affected by the turbid plumes created by dredging. Green and hawksbill turtles feed primarily on rocky reefs and in sponge and soft coral areas, which are uncommon in East Arm. They are thus likely to avoid the dredging area.

Crocodiles and many species of sea snakes frequent shallow coastal areas and mangroves where natural turbidity is high. They are therefore unlikely to be affected by turbid plumes or sedimentation arising from dredging.

Potential Impacts on Fish

Fish assemblages in East Arm constitute an important link in food chains between primary producers and invertebrates and species at higher trophic levels, such as dolphins. In addition, fish in the area are important for recreational fishing and tourism, particularly species such as barramundi, mangrove jack, jewfish and bream. These may be attracted to the dredging area to feed on invertebrates uncovered by the dredging or smaller fish which have themselves been attracted by the exposed invertebrates. In turn the fish may be predated by higher level predators such as dolphins.

Fish species living in East Arm are likely to be adapted to the naturally turbid water conditions. In addition, most fish have a lateral line system which detects vibrations. This helps them to locate prey and avoid predators (Allsop et al., 2003) and lessens the importance of visual cues received by sight.

There could possibly be some mortality to fish through clogging of gills by increased turbidity, although fish would be expected to move away from areas of temporary disturbance. Also, fish mortality would only occur during periods of very high suspended sediment loads, which will be rare during dredging for EAW Project. For example, Jenkins and McKinnon (2006) reported the required levels to be 4,000 mg/L, compared with modelled suspended sediment concentrations during dredging of 5 to 10 mg/L in the vicinity of the dredging operation, above a background range of 6-10 mg/L (refer Section 9.2.1).

Fish eggs and larvae will be more susceptible to suspended sediments than juveniles and adults, with the larvae of some species being adversely affected by concentrations as low as 100 mg/L in a period of 96 hours. These levels will also affect invertebrates such as bivalves and sea urchins. Levels greater than 500 mg/L are likely to produce measurable effects on larvae of most species (Jenkins and McKinnon 2006), but sediment concentrations at this level are not likely to occur during the dredging program. However, as noted above, modelling suggests that suspended sediment concentrations during dredging would be less than 20 mg/L in the vicinity of the dredging operation (refer Section 9.2.1).

15.5.4 Management of Habitat Alteration

The management of potential impacts from the dredging and reclamation works are addressed in the Dredge Management Plan (AECOM, 2011).

Monitoring of the health of mangroves in the vicinity of the Project area will be undertaken during the port expansion construction and dredging works. The monitoring program, to be described in the CEMP, will include parameters related to both mangrove health and habitat condition.

15.5.5 Dredge Spoil Disposal

The disposal of sediments at the offshore spoil disposal ground will cause mortality, through smothering, of benthic fauna therein. Several studies have documented the recovery of spoil ground fauna through recolonisation from adjacent areas, which has begun soon after the impact occured (e.g. Bolam and Rees 2003; Cruz-Motta and Collins 2004; Birklund and Wijsman 2005). The uneven distribution of dredge material appears to enhance the recolonisation process by preserving unaffected patches within the spoil disposal ground, from which recruits are sourced. Further, a faunal community characterised by small, opportunistic deposit feeders, like those that often dominate infauna communities of tropical soft sediments (Alongi 1989), is pre-adapted to rapid recolonisation. At a spoil disposal ground in Cleveland Bay (North Queensland), there was an initial reduction in abundance and diversity of the faunal community, followed by an unexpectedly rapid recovery within three months of the cessation of the disturbance (Cruz-Motta & Collins 2004). Recovery in disturbed, shallow environments (such as the spoil ground) is considered to be faster than in stable, deep environments due to the pre-adaptation of the resident fauna to disturbances (e.g. Bemvenuti, Angonesi & Gandra 2005).

- A summary of the management controls and residual risks for dredge spoil disposal is presented in **Appendix E** and **Appendix Q**. After implementation of controls, potential impacts from dredge spoil disposal are considered to be a “moderate” risk.

15.6 Commitments

- *A Draft DMP has been prepared to address the impacts associated with dredging and dredge spoil disposal, including monitoring to protect environmental values (refer Appendix B). The DMP will be finalised following review through the EIS process and implemented by DPC during the construction period.*
- *A marine pest monitoring program has been established for Darwin Harbour by NRETAS. Discussions will be held with NRETAS to determine the appropriate course of action, in particular on whether the existing program sufficiently covers EAW, or if additional monitoring is required by the EAW Expansion Project. The monitoring program will be included in the CEMP.*

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