Toondah Harbour PDA

Ecological Studies in Support of Works Area Determination

Prepared for:

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frc reference: 141002iii

freshwater estuarine marine

Document Control Summary

Project No.:	140210iii
Status:	Final Report
Project Director:	Dr John Thorogood
Project Manager:	Dr Craig Chargulaf
Title:	Toondah Harbour PDA: Ecological Studies in Support of Works Area Determination
Project Team:	Dr Craig Chargulaf, Cameron Forward, Dr John Thorogood
Client:	Walker Corporation
Client Contact:	Mr Ben Johnson
Date:	November 2014
Edition:	141002iii Final
Checked by:	Dr John Thorogood ________________
Issued by:	Dr John Thorogood ________________

Distribution Record

Walker Corporation: as pdf and Word.docx

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Summary

This report has been developed on behalf of Walker Corporation to respond to Appendix 2 – Environmental Information Requirements prepared by Economic Development Queensland in relation to the Toondah Harbour Priority Development Area (PDA).

The PDA supports a diversity of intertidal and subtidal habitats including mangrove forests and seagrass beds. Each of these habitats extend beyond the PDA and each is widely represented throughout the Moreton Bay region. These habitats provide a range of ecological values and are important for fisheries, biodiversity and ecosystem services.

Mangrove Forests

The intertidal mangrove forests within and around the PDA are dominated by grey mangroves (*Avicennia marina*) and stilted mangroves (*Rhizophora stylosa*), with sparse individual river mangroves (*Aegiceras corniculatum*) and yellow mangroves (*Ceriops australis*). Mangroves were in fair condition with evidence of insect damage, which leads to subsequent leaf loss. Mangroves communities were similar to those found throughout Moreton Bay and typical of south-east Queensland. There are approximately 5.3 ha of mangroves within the PDA that are likely to be of good fisheries and aquatic ecological value.

In the Moreton Bay Marine Park, there are approximately 140 km^2 of mangroves, with the largest communities north of the PDA in Pumicestone Passage and around the southern bay islands. Mangrove forests are important nursery grounds for juvenile fishes, can act as carbon sources, provide organic material for consumption by macroinvertebrates and can trap nutrients and particulate matter buffering the impacts of run-off.

Intertidal and Subtidal Un-vegetated Mudflats and Sand-banks

The sediments within and adjacent to the PDA are bioturbated muds and sands, with a layer of rubble below the surface. The mudflats and sand-banks typically exist between the mangroves in the intertidal zone and the seagrass in the subtidal zone. This area supports a variety of macroinvertebrates that burrow into the sediment. The un-vegetated habitats within the PDA are similar to those found throughout Moreton Bay and are likely to be of good fisheries and aquatic ecological value.

In Moreton Bay, there is over 422 km^2 of subtidal un-vegetated habitat and 75 km^2 of intertidal un-vegetated habitat. Un-vegetated habitats serve an important ecological

function supporting microalgae, benthic invertebrates and can even act as nurseries and refuges for fishes.

Intertidal and Shallow Subtidal Seagrass Meadows

Seagrass within and adjacent to the PDA comprised *Zostera muelleri* and *Halophila ovalis*, with some *Halophila spinulosa*. Seagrass was in low density along the exposed lower intertidal zone and dense in the deeper subtidal area between the current Toondah Harbour and an island of mangroves offshore. The seagrass meadows were healthy, with some signs of degradation (e.g. algal growth), and also supported a variety of macroalgae species. There are approximately 32.7 ha of seagrass within the PDA that are likely to be of good fisheries and aquatic ecological value.

There are seven species of seagrass in Moreton Bay, of which, *Z. muelleri* is the most common and abundant species. Most seagrass in Moreton Bay is intertidal, with subtidal seagrass found in waters less than 3 m deep at low tide. The largest meadows are in the eastern bay near South Passage between Moreton and Stradbroke islands. Seagrassess are primary producers that play a critical role in marine ecosystems. They provide shelter and refuge for fish and invertebrates, trap detritus and organic matter increasing nutrient cycling and provide a food source for marine fauna (e.g. marine turtles and dugongs).

Saltmarsh

There is an area of saltmarsh south of the PDA that is between the landward edge of the mangrove forest and the terrestrial zone. The saltmarsh community is dominated by marine couch (*Sporobolus virginicus*) with common samphire (*Sarcoconia quinqueflora*) and seablite (*Sueda australis*). There is approximately 1.2 ha of saltmarsh south of (and none within) the PDA that is likely to be of fair fisheries and aquatic ecological value.

Saltmarsh communities are listed as vulnerable under the Commonwealth's *Environmental Protection and Biodiversity Protection Act 1999*. There is approximately 84 km^2 of saltmarsh remaining in the Tweed Moreton Bioregion of south-east Queensland. Saltmarshes stabilise bare mud flats, re-mineralise terrestrial and marine debris and may buffer waterbodies from run-off.

Marine Fauna

Marine fauna varied between habitats, but was predominantly dominated by molluscs, crustaceans and polychaetes. The most common and abundant species was the Hercules mud whelk (*Pyrazus ebeninus*) found in the mangrove, mudflat and seagrass habitats. Abundances of epifauna were low in the mangroves and seagrass meadows, and highest on the mudflats.

Benthic infauna was dominated by polychaetes, predominantly from the family Capitellidae, which are considered to be indicators of organic pollution. Benthic infauna abundances were highest in the seagrass and lowest in sand-banks / rubble.

Marine fauna provide a source of food for fish as well as other ecological functions, such as removal of detritus and epiphytic algae from seagrass meadows.

Fish

A variety of commercial fisheries operate within Moreton Bay, to the east of the PDA. Prawns and Balmain bugs are targeted by trawl fisheries and fish are targeted by net fisheries. Recreational fisheries is also common throughout Moreton Bay with an annual catch of approximately 8.1 M tonnes.

The habitats within the PDA provide a range of ecological values important for the maintenance of fisheries resources and biodiversity. A number of seahorse, pipefish and pipehorse species that occur in southern Moreton Bay are listed marine species under the EPBC Act, and protected within Commonwealth Marine waters. However, they are not protected in the State waters of the Moreton Bay Marine Park of the PDA.

Turtle, Dolphin and Dugong

All of Australia’s six species of marine turtles occur in Moreton Bay. Moreton Bay is an important feeding ground for marine turtles and the species rely on the seagrass meadows; however, marine turtle distribution is mostly confined to the eastern sections.

Several dolphin species occur in Moreton Bay, but boat traffic from the current ferry terminal at Toondah Harbour is likely to deter dolphins from the area. Nonetheless, dolphins may occasionally feed over the tidal flats.

Approximately 800 to 900 dugongs are known to live within Moreton Bay. Dugong populations are mostly confined to the South Passage Bar and around Moreton and Amity Banks. Dugongs typically avoid areas of high human activity, such as Toondah Harbour, but they may occasionally feed on the seagrass in the area.

A Preliminary Analysis of Impacts and the Sensitivity of Marine Plants and Animals

The discussion of impacts presented here is preliminary, and based on the indicative development footprint, indicating extensive dredging and reclamation to support residential development and a marina. Potential impacts that may be associated with the PDA include:

- Construction Phase
  - loss of marine plants
  - loss of benthic habitat
  - increased turbidity and sediment deposition
  - change in community structure of benthic communities
  - gain of new marine habitat
  - fish trapped in wet excavation area by silt curtains
  - loss of area for recreational fisheries
  - marine mammals and reptiles trapped in the wet excavation area by silt curtains
  - damage of marine mammals and reptile
  - disturbance of acid sulfate and potential acid sulfate soils
  - hydrocarbon contamination, and
  - increase in human activity and noise.
- Operation Phase
  - increased boat traffic and access
  - altered hydrodynamics
  - chronic hydrocarbon contamination
  - contamination by heavy metals
  - increased litter in the aquatic environment
  - introduction of pest species, and
  - cumulative impacts (e.g. boat traffic and recreational fishing).

1 Introduction

This report, developed on behalf of Walker Corporation, responds to elements of Appendix 2 – Environmental Information Requirements prepared by Economic Development Queensland in relation to the Toondah Harbour Priority Development Area (PDA), and specifically supports the determination of a Works Area.

Our understanding of the proposed development of the PDA is primarily based on the preliminary design sketch shown in Figure 1.1. The proposed development involves extensive dredging and reclamation to support expansion of existing commercial operations, residential development and a marina.

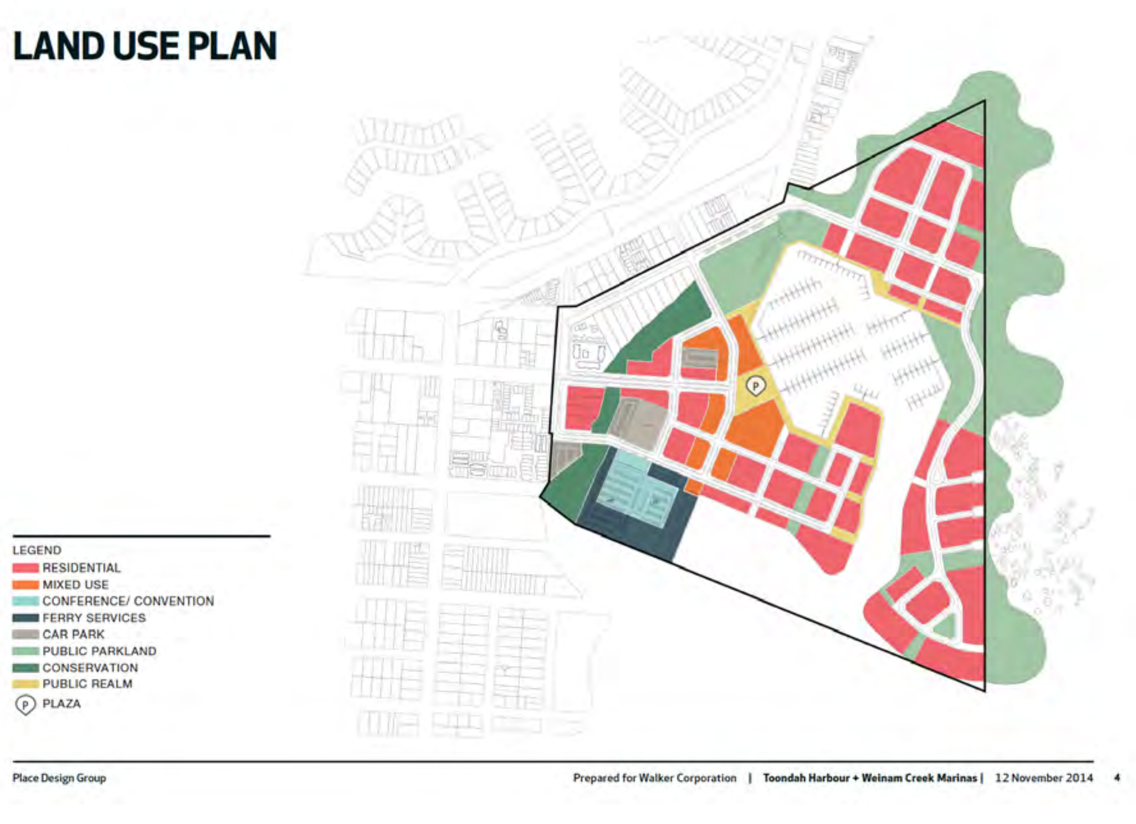


Figure 1.1 Indicative Land Use Plan (from Place Design Group).

This report describes the marine plants and benthic habitat currently within and adjoining the PDA, the aquatic fauna associated with that habitat, and discusses how the proposed development may impact habitat and associated flora and fauna.

2 Marine Plants / Habitats

2.1 Overview

The PDA supports a diversity of intertidal and shallow subtidal habitat, notably:

- saltmarsh
- intertidal mangrove forest
- intertidal un-vegetated mudflats and sand-banks
- intertidal and shallow subtidal seagrass meadows; and
- subtidal un-vegetated mud (including the existing dredged navigation channel) (Map1).

Each of these habitat types extends beyond the PDA; and each is extensively distributed throughout western Moreton Bay.

Estuarine systems are a 'seascape' of interconnected patches of habitat (including seagrasses, mangroves, saltmarshes, oyster reefs and rubble banks, and un-vegetated sand-banks and mudflats), linked actively through the movement of organisms and passively through the waterborne transport of primary production (Irlandi & Crawford 1997; Loneragan et al. 1997; Micheli & Peterson 1999; Rapoza & Oviatt 2000; Connolly & Guest 2002; Skilleter & Loneragan 2003; Skilleter et al. 2005). These habitats provide a range of ecological values and are important for the maintenance of fisheries resource, biodiversity and ecosystem services, and often support a high abundance and diversity of fish and invertebrates (Beck et al. 2001). In addition to sustaining adult populations, which are harvested by inshore fisheries, many habitats are widely recognised for their role as 'nurseries' for juvenile fish, crabs and prawns, and their contribution to the productivity of offshore fisheries (Coles & Lee-Long 1985; Connolly 1994; Laegdsgaard & Johnson 1995; Halliday & Young 1996; West & King 1996; Blaber 1997; Butler et al. 1999; Beck et al. 2001; Chargulaf et al. 2011).

Toondah Harbour PDA Ecological Studies in Support of Works Area Determination

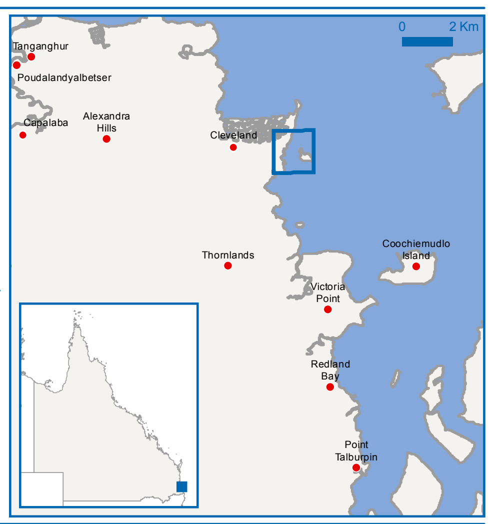
Map 1: Marine habitats of Toondah Harbour

LEGEND

- Toondah Harbour PDA
- Indicative Extent of Reclamation

Dominant Marine Habitats

- *Avicennia marina*
- *Rhizophora stylosa*
- *Aegiceras corniculatum*
- *Ceriops tagal var. australis*
- Saltpan / Saltmarsh
- *Juncus kraussii*
- Seagrass
- Rubble
- Sand / Mud



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2.2 Mangrove Forests

2.2.1 Of the PDA

The intertidal mangrove forest is dominated by the grey mangrove (*Avicennia marina*) and the stilted mangrove (*Rhizophora stylosa*), with sparse river mangroves (*Aegiceras corniculatum*) and yellow mangroves (*Ceriops australis*) in the upper intertidal zone (Map 1). The grey mangrove dominated the lower and upper intertidal zones, while the stilted mangrove dominated the middle intertidal zone (Figure 2.1). Mangroves were in fair condition, with evidence of insect damage (Figure 2.2) throughout the PDA. There was some yellowing of leaves (Figure 2.3), which can be attributed to stress or can be related to low rainfall and high salinity in the sediment. There were few dead mangrove trees and the presence of dead branches was approximately 20% in some areas. The density of seedlings was low with the most seedlings being recorded in the mangrove forest north of the current ferry terminal.

Mangrove communities offshore, east of the PDA, are dominated by the grey mangrove, with some stilted mangrove in the middle of the island (Map 1). The condition of the mangroves was similar to that of the intertidal mangrove forests, with some dead branches and insect damage.

Mangrove communities of the PDA were similar to those found around Moreton Bay and typical of south-east Queensland being low in diversity and dominated by the grey mangrove. There are approximately 5.3 ha of mangroves within the PDA that are likely to be of good fisheries and aquatic ecological value (Table 2.1).

Figure 2.1

Dense *Rhizophora stylosa* south of the current ferry terminal within the PDA.

Figure 2.2

Insect damage on grey mangrove leaves.

Figure 2.3

Yellowing leaves of stilted mangroves.

Table 2.1 Mangrove habitat description.

Description	Species Included	Value to Fisheries	Aquatic Ecological Value
The mangrove forests are along the upper intertidal zone and are bordered by mud and sand flats. This area is within the Moreton Bay Marine Park. The mangrove forests are highly disturbed by the developed areas along the foreshore. There mangrove forests receive run-off from developed areas and rubbish was found within the mangrove roots and shoreline throughout the PDA.	**Plants** Black mangrove River mangrove Stilted Mangrove Yellow Mangrove Benthic algae **Invertebrates** Hercules mud whelks Barnacles Periwinkles Nerites Estuarine slugs Hermit crabs Sand bubblers Fiddler crabs	Good The area is regularly inundated and he density of invertebrates was low; however, diversity was moderate.	Good Diversity of flora was low, but cover was high. The diversity of fauna was high, but abundances were low. The area is unlikely to provide significant habitat for species of conservational significance.

2.2.2 Regional Context

The mangroves of Queensland have been divided into three broad communities: high rainfall forest communities; low rainfall claypan communities; and subtropical communities (Dowling & McDonald 1982). Within the Toondah Harbour PDA, mangroves are typical of the subtropical communities. Subtropical mangrove communities are floristically less diverse than the other two community types, primarily because they are at the southern limit of many species ranges (Dowling & McDonald 1982).

There are seven species of mangrove in Moreton Bay (and in the Moreton Bay Marine Park); grey mangroves (*A. marina*), river mangroves (*A. corniculatum*), large-leaved mangroves (*Bruguiera gymnorrhiza*), yellow mangroves (*Ceriops australis*), milky mangroves (*Excoecaria agallocha*), white flowered black mangroves (*Lumnitzera racemosa*), and stilted mangroves (*R. stylosa*). The mangrove fern, *A. speciosum*, is also common (Dowling 1979; 1986; Hyland & Butler 1988; Dowling & Stephens 2001). In the Moreton Bay Marine Park there are approximately 140 km^2 of mangroves, with the largest communities in Pumicestone Passage and the southern bay islands, south of Jacobs Well (DERM 2010).

2.2.3 Ecological Significance

Mangrove forests are important nursery grounds for many species of juvenile fishes, including commercially important species (Robertson & Blaber 1992; Laegdsgaard & Johnson 1995; Halliday & Young 1996; Blaber 1997) (e.g. sea mullet, Figure 2.4). Juveniles of seven from the ten commercially harvested fish species in Moreton Bay are most abundant in mangroves (Laegdsgaard & Johnson 1995). Further, Morton (1990) reported that 46% by species and 94% by weight, of fishes associated with an *A. marina* forest in Moreton Bay were of direct commercial significance.

Mangrove lined creeks support a variety of fish species that have habitat-specific distributions according to individual species requirements for food and shelter (Zeller 1998). Mangrove forests can act as carbon sources for estuarine, inshore, and offshore waters, through the export of leaf and fruit material (Lee 1995). Decomposing mangrove material provides both soluble nutrients and detrital fragments that are eaten by crustaceans, such as prawns and crabs, and some fish. Decaying plant and animal matter are consumed by juvenile and adult greasy back prawns, and juvenile banana prawns, both of which are obligate residents of mud banks adjacent to mangroves (Staples & Vance 1985). Adult banana prawns eat both small benthic invertebrates feeding on detritus in channels draining mangroves, and benthic algae on adjacent mud flats (Newell et al. 1995). Mangroves also trap, accumulate and release nutrients (and in some cases pollutants) and particulate matter (silt) from surrounding land, thus acting as a buffer to the direct effects of run-off. They also protect the shoreline from erosion from the water (e.g. waves and boat wash) or the land (run-off), and contribute to the establishment of islands and the extension of shorelines (Blamey 1992).

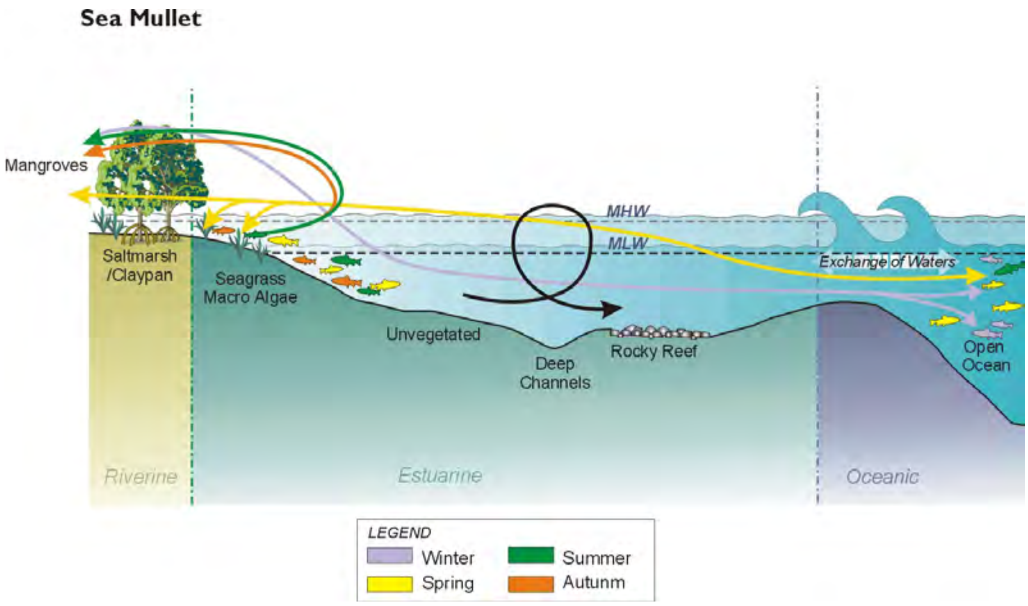


Figure 2.4 Mangroves provide critical habitat for young sea mullet.

2.3 Intertidal and Subtidal Un-vegetated Mudflats and Sand-banks

2.3.1 Of the PDA

The sediments within and adjacent to the PDA are bioturbated muds and sands, with sparse areas of exposed rubble (comprising rocky material and shell fragments). There is a layer of rubble that is below the muds and sands throughout the PDA and can range from 0.1 to 0.6 m below the surface. The area of muds and sands typically extended from the mangroves into the existing channel or to seagrass beds north of the channel. The muds and sands were not compacted, easily displaced and had a high density of holes for burrowing fauna (i.e. crabs and polycheates) (Figure 2.5). The un-vegetated mud and sand habitats were similar to those found throughout Moreton Bay (e.g. Godwin Beach, Manly and Nudgee Beach) with the exception of being less compacted. Overall, the mud and sand flats of the PDA were likely to be of good fisheries and aquatic ecological value (Table 2.2).

Figure 2.5

Mudflat substrate and associated fauna burrows within the PDA.

Table 2.2 Intertidal and subtidal un-vegetated mud and sand habitat description.

Description	Species Included	Value to Fisheries	Aquatic Ecological Value
This zone is along the lower intertidal zone and includes the current dredged channel for boat and ferry access to Moreton Bay. The un-vegetated mud and sand habitat is bordered by mangrove forests in the upper intertidal zone and seagrass beds in the subtidal areas. This area is within the Moreton Bay Marine Park. The area around the channel is extremely disturbed by the frequent boat and ferry traffic, with wash affecting exposed areas at low tide. The rest of the area is moderately disturbed, with run-off from developed areas and some recreational use.	**Plants** Benthic algae **Invertebrates** Hercules mud whelks Hermit crabs Fiddler crabs Mangrove crabs Polychaetes	Good The density of burrowing invertebrates holes was moderate throughout the mud and sand flats. Evidence of stingray foraging pits was also present.	Good There was some diversity and abundance of fauna; however, the area is unlikely to provide significant habitat for species of conservational significance.

2.3.2 Regional Context

Brisbane River sand has been deposited in a river delta protruding into the bay, and some of this material has been transported by waves to form tidal flats, predominantly to the north. A belt of river-derived prodelta mud (up to 5 m thick) has been deposited along the western side of the bay, extending to about 10 – 15 m water depth (Maxwell 1970; Hekel et al. 1979; Jones & Stephens 1981).

Marine sand has been deposited between Bribie Island and Moreton Island, and between Moreton Island and North Stradbroke Island. The central, deeper part of the bay receives no sand and very little mud.

Bioturbated mud and sand is the dominant habitat of western Moreton Bay. There is over 422 km^2 of subtidal un-vegetated habitat and 75 km^2 of intertidal flats in Moreton Bay (Ozcoasts 2009) (Figure 2.6).

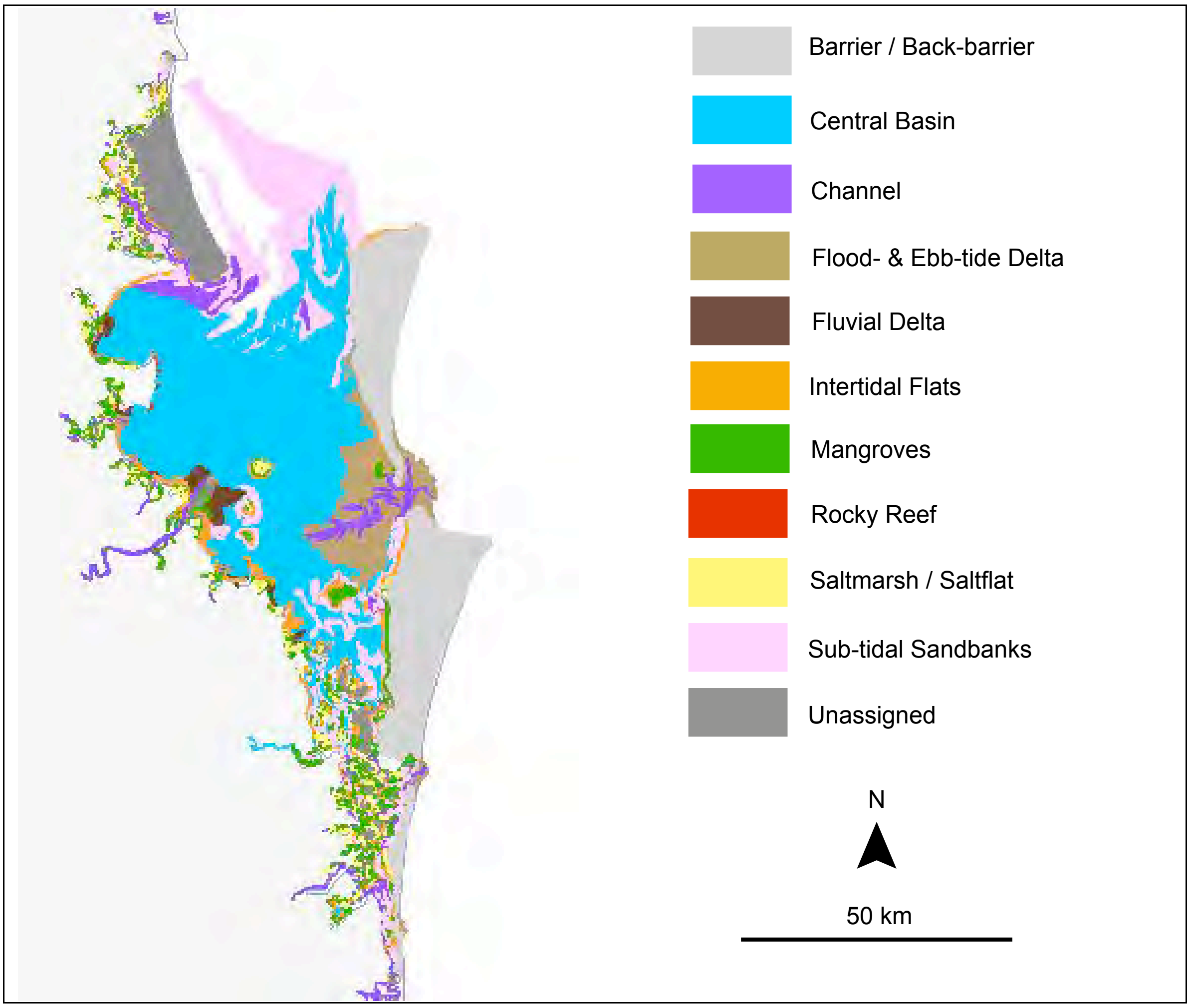


Figure 2.6 Geomorphic Habitats in Moreton Bay.

2.3.3 Ecological Significance

Un-vegetated sandy and muddy sediment, whilst commonly considered to be not as productive as areas supporting seagrass, are also important to the ecosystem. Bare substrate is rarely bare. Where sediments are stable, microalgae communities become established within both the intertidal and shallow subtidal. The microalgae support an associated community of small benthic invertebrates (e.g. polychaete and nematode worms, cumaceans, copepods and soldier crabs), which in turn are an important source of food for fishes, such as bream and whiting (Weng 1983). Soft sediment tidepools are formed at low tide, which support a variety of fishes and can serve as a nursery for juveniles, such as whiting (Chargulaf et al. 2011). Laegdsgaard and Johnson (1995) suggest mudflat habitats may be transitional zones between juvenile and adult habitats. Bare substrates in shallow waters may also provide shelter from larger predators and the opportunity to employ camouflage: whiting, flathead and flounder are examples of species positively associated with bare substrate habitat.

Intertidal and shallow subtidal sand flats support a variety of fish species. Fish, such as whiting and flathead, feed in sandy areas; whereas fish, such as bream and mullet, prefer the fauna associated with muddy areas (Figure 2.7). In southern Moreton Bay, the yellowfin bream is perhaps the best known example of a species that migrates to surf bars to spawn (Pollock et al. 1983). Shallow surf bars are also the spawning grounds for whiting, flathead, luderick, tailor and mullet.

Bream, juvenile sand whiting and other species of commercial and recreational importance feed over and along the edges of sand banks (Morton et al. 1987). Female sand crabs are associated with sand banks, whilst males are likely to be found in adjacent gutters (Smith & Sumpton 1987). Bait species important to both commercial and recreational fishers inhabit intertidal and shallow subtidal banks of sheltered bays (e.g. worms) and estuaries (e.g. yabbies) (Zeller 1998).

The fauna associated with soft sediment habitats is typically determined by the character of the sediment: its grain size and stability; and with the presence or absence (Poiner 1980; Humphries et al. 1992), or proximity of seagrass (Ferrell & Bell 1991). Grain size influences the ability of organisms to burrow, and the stability of ‘permanent’ burrows. Unstable sediments support less diverse benthic communities than those that are relatively stable. Bare sediments within 10 m of seagrass meadows were shown to support a similar total abundance of fishes, but a reduced diversity of species when compared with the nearby *Zostera* meadows themselves; whereas bare substrate 100 m distant from the seagrass meadows supported significantly fewer individuals and species (Ferrell & Bell 1991). In partial contrast, studies of bare substrate and nearby *Ruppia* meadows showed finfish diversity to be higher over bare substrate, but abundance and biomass highest in the seagrass meadows (Humphries et al. 1992).

Shallow water, bare sediment communities are characterised by widely fluctuating abundances, species richness and diversity. These fluctuations are correlated with severe abiotic disturbances (e.g. wind and wave activity). During calmer months, shallow bare sand developed similar communities to deep-water bare sand habitats (Poiner 1980).

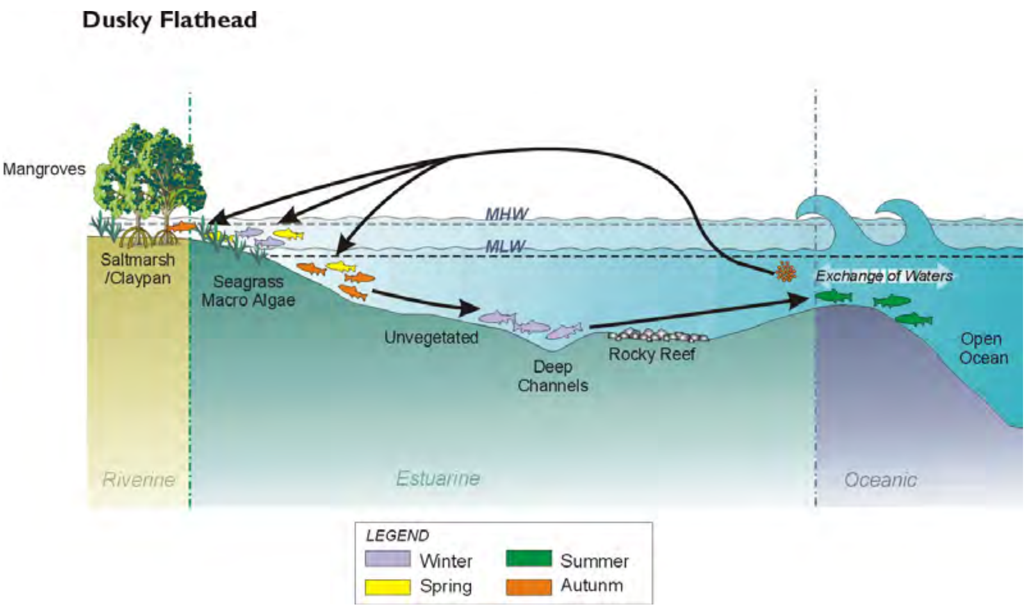


Figure 2.7 Un-vegetated sand and mud substrates are a preferred habitat of dusky flathead.

2.4 Intertidal and Shallow Subtidal Seagrass Meadows

2.4.1 Of the PDA

Seagrass is known to be ephemeral with area, density and depth distribution dependent largely on water turbidity. Beds are likely to increase in area and density with the clearer water associated with drought and low rainfall conditions, and decrease with higher turbidity associated with high rainfall and floods. In November 2014, patches of seagrass were observed on the exposed flats in the lower intertidal zone and in the adjacent subtidal zone within the eastern boundaries of the PDA. The seagrass meadows predominantly consisted of *Zostera meulleri* with sparse amounts of *Halophila ovalis* (Figure 2.8). There were also trace amounts of *Halophila spinulosa* throughout the seagrass meadows (Figure 2.9). Seagrass was dense in the subtidal zone between the current ferry terminal and the island of mangroves offshore (Figure 2.10). There was low cover of seagrass in the exposed lower intertidal zone adjacent to the mud and sand flats. Seagrass meadows were in good condition; however, there were some patches of seagrass that were covered in filamentous algae. Within the seagrass meadows, several species of macroalgae were also identified, including:

- sargassum (*Sargassum flavicans*)
- *Padina gymnospora*
- oyster thief (*Colpomenia sinuosa*), and
- coralline algae (*Halimeda* spp.).

Stingrays were observed foraging in the seagrass at low tide, and several species of fish were observed entering the seagrass meadow on the incoming tide. The composition and cover of the seagrass meadows within the PDA are similar to other coastal seagrass meadows located throughout Moreton Bay.

There are approximately 32.7 ha of seagrass within the PDA that are likely to be of high fisheries and aquatic ecological value (Table 2.3).

Figure 2.8

Seagrass meadow comprising *Zostera meulleri* and *Halophila ovalis* within the PDA.

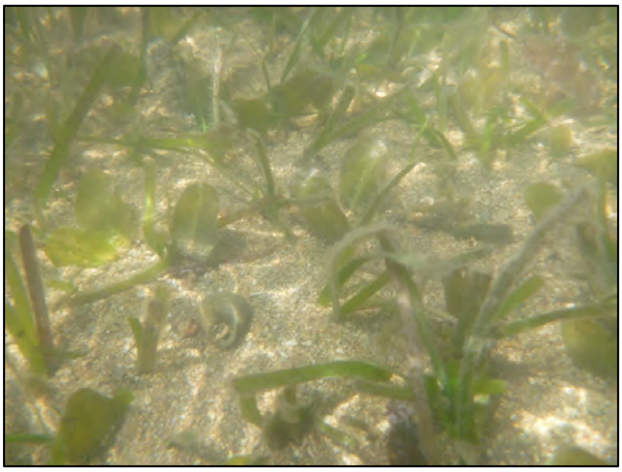


Figure 2.9

Halophila spinulosa.

Figure 2.10

Dense seagrass cover in the subtidal zone.

Table 2.3 Seagrass habitat description.

Description	Species Included	Value to Fisheries	Aquatic Ecological Value
The seagrass meadows are predominantly in the subtidal zone between the foreshore and island of mangroves offshore within the PDA. There are also some sparse seagrass meadows in the lower intertidal zone adjacent to the subtidal areas. This area is within the Moreton Bay Marine Park. The seagrass meadows have low disturbance by recreational boat traffic and wash from ferries on the southern section adjacent to the channel.	**Plants** Seagrass Macroalgae **Invertebrates** Hermit crabs Sea cucumbers Anemones Swimmer crabs Polychaetes Soft Corals Jellyfish Shrimp Mussels Clams **Vertebrates**	High The density of seagrass provides high cover for juvenile fish and invertebrates. Invertebrates were observed among the seagrass and under large rocks. Stingrays and fish were observed using the seagrass beds throughout the tidal cycle.	High There was moderate diversity and abundance of flora and fauna. The area is likely to be used by several fish species of commercial importance. The area potentially provides significant habitat for species of conservational significance as well as being a foraging ground for marine turtles and dugongs, which are both known to occur in Moreton Bay.

2.4.2 Regional Context

There are seven species of seagrass in Moreton Bay (and in Moreton Bay Marine Park): *Cymodocea serrulata*, *H. ovalis*, *H. spinulosa*, *Halophila decipiens*, *H. uninervis*, *Syringodium isoetifolium*, and *Z. muelleri*. *Z. muelleri* is the dominant species in terms of area. Most seagrass in Moreton Bay is intertidal, with subtidal seagrass generally found in water less than 3 m deep at low tide (Hyland et al. 1989). Over 280 species of macroalgae have been recorded from Moreton Bay (Tibbetts et al. 1998). *Caulerpa taxifolia* is a green algae commonly found in Moreton Bay in the same shallow, soft sediment niche as seagrass (Phillips & Price 2002; Thomas 2003), but was not recorded in the Toondah Harbour PDA.

The largest and most dense seagrass meadows are in the eastern bay surrounding South Passage between Moreton and Stradbroke islands; though there are also substantial meadows in the southern and western parts of the bay. With increasing urbanisation and industrial development, seagrass meadows within western Moreton Bay have been lost over the past decades. While some meadows have been lost as a direct result of infilling, a far greater area of seagrass has been lost as a result of changes in water quality (EHMP 2006).

2.4.3 Ecological Significance

Seagrasses are primary producers (Hillman et al. 1989) that are recognised as playing a critical role in coastal marine ecosystems (Pollard 1984; Poiner & Roberts 1986; Hyland et al. 1989). They provide shelter and refuge for resident and transient adult and juvenile finfish, crustaceans and cephalopods, many of which are of commercial and recreational importance, others of which are the preferred foods of these species (Dredge et al. 1977; Hutchings 1982; McNeill et al. 1992; Coles et al. 1993; Edgar & Shaw 1995; Gray et al. 1996; Connolly 1997) (Figure 2.11). They also have a number of other ecological functions including providing large amounts of substrate for encrusting animals and plants (Harlin 1975; Klumpp et al. 1989) and trapping detritus and dissolved organic matter, increasing local nutrient cycling (Moriarty et al. 1984).

Whilst the abundances of juveniles of many fish and crustacean species are commonly higher in seagrass habitats than over bare sand or mud, there are also significant differences in abundance between seagrass meadows (e.g. Gray et al. 1996). Some sites have consistently higher recruitment (McNeill et al. 1992), whilst other sites may periodically or temporarily have higher abundances (Gray et al. 1996; Connolly 1999). This may be due to a variety of factors including structural complexity of the seagrass meadows; location of the seagrass meadows with respect to currents and the dispersal of larvae; and natural fluctuations (patchiness) in population sizes (Gray et al. 1996; Connolly 1999). To date the importance or fisheries values of seagrass has largely been measured by the absolute abundance of fauna found in it. However, seagrass habitat may also provide important linkages and refuges between different habitat types (e.g. mangroves and seagrass), and between up and downstream communities. Thus, whilst a seagrass meadow may not support high abundances of fish or crustaceans at any one time, over a period of time many individuals may use it as they pass through to other areas.

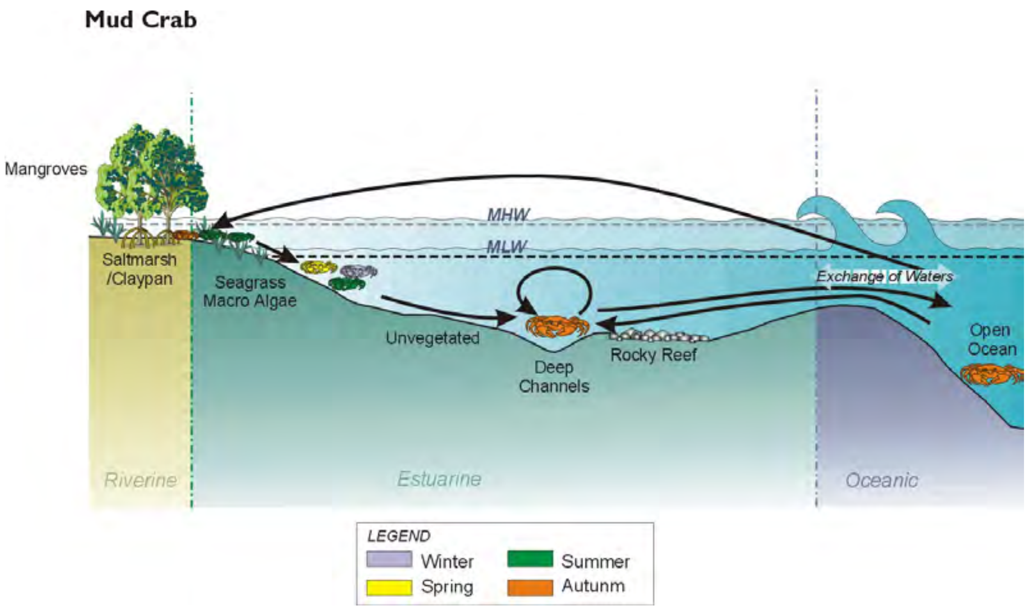


Figure 2.11 Seagrass meadows provide important shelter for juvenile mud crabs.

2.4.4 Factors Affecting Seagrass Distribution

Seagrass distribution is most affected by light intensity, desiccation, and nutrient levels. Other factors, such as currents, substrate suitability, prior patterns of distribution, dispersion of propagules, grazing by turtles and dugongs, and episodic events (including cyclones and floods) also play roles in determining the distribution of seagrass.

Of these factors, light availability is often the most important in determining the distribution of seagrass. The amount of light reaching a seagrass meadow is the combination of the light intensity at the surface, the depth at which the seagrass is growing, the turbidity of the water, and the presence or absence of epiphytes on the seagrass. Light availability, or specifically the duration of light intensity exceeding the photosynthetic light saturation point controls the depth distribution of seagrass (Dennison & Alberte 1985; Dennison 1987; Abal & Dennison 1996). For example, on average 30% of surface light; a light attenuation co-efficient of less than 1.4 m^{-1} and median total suspended solids of less than 10 mg/L are required for the survival of *Z. muelleri* (Abal & Dennison 1996; Longstaff et al. 1998). *H. ovalis*, on the other hand, has a particularly low tolerance to light deprivation caused by pulsed turbidity, such as floods and dredging (Longstaff et al. 1998).

Availability of light also affects the productivity of seagrass. Seagrass exposed to high light intensity are more productive than seagrass in less intense light (Grice et al. 1996). Consequently, impacts associated with dredging may result in at least a temporary decrease in seagrasses productivity. Light also controls the population dynamics of macroalgae (Lukatelich & McComb 1986a; cited in Lavery & McComb 1991).

Both *H. ovalis* and *H. spinulosa* are opportunistic species, producing large quantities of seeds and with relatively high growth rates. This enables them to quickly colonise areas when conditions are suitable; however, they also rapidly disappear when conditions deteriorate.

Currents and changes in sedimentation are also likely to be significant in determining the distribution of seagrass in Moreton Bay.

2.5 Saltmarsh

2.5.1 Adjacent to the PDA

There is an area of saltmarsh south of the PDA that extends from the landward edge of the mangrove zone up to the terrestrial zone (Figure 2.12). The saltmarsh community is dominated by marine couch (*Sporobolus virginicus*) with patches of common samphire (*Sarcoconia quinqueflora*) (Figure 2.13) and seablite (*Sueda australis*). Along the upper most portion of the saltmarsh, there was a dense zone of sea rush (*Juncus kraussii*) (Figure 2.14).

There are approximately 1.2 ha of saltmarsh south of (and none within) the PDA. The saltmarsh is in fair condition and unlikely to be of fair fisheries and aquatic ecological value (Table 2.4).

Figure 2.12

Saltmarsh south of the PDA.

Figure 2.13

Common samphire.

Figure 2.14

Sea rush.

Table 2.4 Saltmarsh habitat description.

Description	Species Included	Value to Fisheries	Aquatic Ecological Value
The saltmarsh is along the upper most intertidal zone and are bordered by the mangrove forest. This area is within the Moreton Bay Marine Park. The saltmarsh is highly disturbed by the developed areas along the foreshore. The saltmarsh receives run-off from developed areas and rubbish was found throughout.	**Plants** Black mangrove River mangrove Sea rush Seablight Samphire Couch Benthic algae	Fair The area is only inundated on high spring tides and no invertebrates were observed.	Fair Diversity of flora was low and patchy. The area is unlikely to provide significant habitat for species of conservational significance. However, the habitat is listed as vulnerable under the EPBC Act.

2.5.2 Regional Context

Claypan habitats in Moreton Bay are seldom vegetated, but may have occasional patches of samphire (*Sarcocornia* spp.) and marine couch (*S. virginicus*) (Dowling & Stephens 2001). Samphire communities are dominated by samphire and seablight (*Suaeda* sp.). Grassland communities are dominated by saltwater couch (*Paspalum vaginatum*) and patches of rush, such as *Juncus kraussii* (Dowling & Stephens 2001).

Within Moreton Bay, there are approximately 368 ha of samphire and 2 034 ha of claypan habitat (Beumer et al. 2012).

Subtropical and temperate coastal saltmarsh is listed as vulnerable under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act 1999*. The listed coastal saltmarsh community consists of dense to patchy areas of mainly salt-tolerant vegetation that is generally less than 0.5 m high and bare sediment (clay). This habitat occurs throughout Moreton Bay, including south of the PDA.

2.5.3 Ecological Significance

Saltmarsh areas provide permanent habitat for a number of animals, including crabs, mosquitoes and other insects. Large clutches of crab larvae are produced in saltmarsh areas during the spring tides when the marsh is inundated; in fact, the highest concentrations of zooplankton in estuaries are found in spring tides in saltmarshes (Saintilan & Mazumder 2004). This concentrated release of plankton into the water column can be an important food source for other organisms, such as fish, including some commercially important species (Saintilan & Mazumder 2004; Mazumder et al. 2006). As well as providing prey for wader birds and other animals, crabs perform bio-turbation and nutrient cycling functions vital for the ongoing health of saltmarsh communities.

Saltmarshes stabilise bare mud flats; re-mineralise terrestrial and marine debris; and may buffer the water bodies from excess terrestrial nutrient run-off (Adam 1990). Saltmarsh communities and their role in intertidal habitats are poorly understood, especially in Australia. Saltmarsh communities may export carbon, act as fish habitats during inundation, stabilise bare mud flats and reduce erosion in the upper intertidal zone (van Erdt 1985, cited in Adam 1990). Saltmarshes are involved in re-mineralisation of terrestrial and marine debris, contribute to the nutrient cycling of estuaries, and may buffer water bodies from excess nutrients from the land (Adam 1990). Within the Tweed Moreton Bioregion in south-east Queensland, only 84 km^2 of saltmarsh communities remain (Dixon et al. 2011).

Whilst our understanding of the direct use of saltmarshes by finfish and nektonic crustaceans is comparatively poor (Connolly 1999), some studies have indicated that fish of commercial and recreational importance rarely use upper littoral saltmarsh habitat (Morton et al. 1987; Connolly et al. 1997), while others have found widespread use of saltmarshes by a range of common and commercially important fish species (Thomas & Connolly 2001).

3 Marine Fauna

3.1 Invertebrate Epi- and Infauna

Each of the habitats described in Section 2 of this report support an assemblage of invertebrate epi- and infauna. Details of survey and sample collection are detailed in Section 5.

3.1.1 Of the Mangroves

Epifauna of the mangroves was dominated by various mollusc species. Whelks and periwinkles were common on mangrove branches and roots (Figure 3.1), while Hercules mud whelks (*Pyrazus ebeninus*) were common on the substrate. Nerites (*Nerita* spp.) were also recorded on mangrove branches and roots (Figure 3.2). Maroon mangrove crabs (*Perisesarma messa*) were caught in pitfall traps, while broad-fronted mangrove crabs (*Metopograpsus frontalis*) (Figure 3.3) were recorded using crab holes around pneumatophores.

Figure 3.1

Mangrove whelk (*Batillaria australis*) on mangrove trunk.

Figure 3.2

Nerite on stilted mangrove prop root.

Figure 3.3

Broad-fronted mangrove crab.

3.1.2 Of the Intertidal Mudflats

Epifauna of the intertidal mudflats was dominated by Hercules mud whelks with some fiddler crabs (*Uca* spp.). Sand bubbler crabs were caught in pitfall traps and there was evidence of their foraging on the mudflats.

Benthic infauna was dominated by polychaetes with some crustaceans, bivalves and gastropods. Polychaetes were dominated by individuals from the family Capitellidae, which are considered to be indicators of organic pollution (Beesley et al. 2000). Abundances varied between the two sites, with lower abundances in the mudflats south of the channel; however, taxonomic richness was similar between sites (Table 3.1).

Table 3.1 Mean abundance per square meter and total taxonomic richness of benthic infauna at each site.

Site	Mean Abundance (± SE)	Total Taxonomic Richness
Mud 1	267 (± 109)	10
Mud 2	967 (± 303)	9

3.1.3 Of the Intertidal Sand-banks

Epifauna of the intertidal sand-banks were similar to the mudflats and dominated by Hercules mud whelks. No other fauna was recorded on the sand and rubble banks in the PDA.

Benthic infauna was minimal and was dominated by polychaetes, with crabs at site Rubble 1 and a bivalve at site Rubble 2. Polychaetes were all from the family Capitellidae, except for one sample where polychaetes from the family Cirratulidae were recorded. Abundances and taxonomic richness of benthic infauna varied between sites and were highest at the site adjacent to the channel (Table 3.2).

Table 3.2 Mean abundance per square meter and total taxonomic richness of benthic infauna at each site.

Site	Mean Abundance (± SE)	Total Taxonomic Richness
Rubble 1	200 (± 0)	6
Rubble 2	83 (± 67)	3

3.1.4 Of the Intertidal and Subtidal Seagrass

Epifauna of the seagrass beds was sparse, with low numbers of individuals recorded. At low tide, Hercules mud whelks were in the seagrass near the more exposed areas (Figure 3.4), while blue swimmer crabs (*Portunus armatus*) were present in the subtidal areas (Figure 3.5). Two bivalves were recorded in seagrass beds; the strawberry cockle (*Fragum unedo*) (Figure 3.6) and the razor clam (*Pinna bicolor*). Several anemone species (e.g. Figure 3.7) and some small colonies of soft corals were also identified. One sea cucumber was found under a rock in the seagrass beds; however, no other sea cucumbers were observed on the seagrass in the intertidal or subtidal zone.

Benthic infauna was dominated by polychaetes and crustaceans, with some bivalves and gastropods. Polychaete communities comprised several families including Capitellidae, Cirratuliade, Syllidae and Spionidae. Crustacean communities comprised Gammarid amphipods, snapping shrimp (family Alpheidae) and hermit crabs (family Diogenidae). Brittle stars (class Ophiuroidea) were recorded at site Seagrass 2 in the shallower subtidal area. The abundance and taxonomic richness of benthic infauna was highest at site Seagrass 2 (Table 3.3), despite site Seagrass 1 being deeper and less exposed at low tide.

Table 3.3 Mean abundance per square meter and total taxonomic richness of benthic infauna at each site.

Site	Mean Abundance (± SE)	Total Taxonomic Richness
Seagrass 1	333 (± 17)	13
Seagrass 2	1583 (± 246)	24

Figure 3.4

Hercules mud whelk in shallow seagrass.

Figure 3.5

Blue swimmer crab in the seagrass.

Figure 3.6

Cockle exposed at low tide.

Figure 3.7

Sea anemone among seagrass.

3.1.5 Of the Subtidal Mud (Channel)

Benthic infauna was dominated by polychaetes, with some crustaceans. Polychaete communities were dominated by the families Magelonidae and Cossiuridae, while crustaceans were dominated by the family Tanaidacea. The abundance and taxonomic richness in the channel was relatively similar between sites (Table 3.4).

Table 3.4 Mean abundance per square meter and total taxonomic richness of benthic infauna at each site.

Site	Mean Abundance (± SE)	Total Taxonomic Richness
Channel 1	550 (± 144)	8
Channel 2	700 (± 200)	11

3.1.6 Regional Context

There are two relatively diverse bioregions for invertebrate communities within Moreton Bay: the western bay – dominated by estuarine species; and the eastern bay – dominated by marine species (Davie 1998). Diversity in the western bay is attributable largely to infaunal communities (living within the sediment), while communities in the eastern bay comprise a large number of infaunal and epibenthic (on the surface) invertebrates such as corals and ascidians.

Communities in the western bay are characterised by infaunal or mobile epibenthic species tolerant of high turbidity and sedimentation levels, such as crustaceans, worms and echinoderms (Davie 1998).

Diversity in the western bay is highest near the mouth of the Brisbane River and declines steadily to the north (Davie 1998). Some unvegetated sandbanks are exceptionally species poor, while others throughout Moreton Bay support diverse assemblages of finfish and decapod crustaceans (Lasiak 1986; Brown & McLachan 1990; Kailola et al. 1993; Morrison 1996). Bare sand and mud flats support different communities to vegetated areas, and are particularly important for some species of whiting and prawn.

3.1.7 Factors Influencing Benthic Invertebrate Communities

The structure of benthic macroinvertebrates communities is influenced by a suite of factors including nutrient loads, sediment grain size and turbidity. As they are largely immobile, and quickly respond to changes in these factors, changes in their community structure can be used as a tool to assess the ecological health of waterways, and to identify characteristics of pressures acting on those waterways. With the use of control sites, and temporally replicated baseline monitoring, they can also be used to assess the impacts of a development.

Increases in sediment organic and nutrient loads often leads to a reduction in community diversity and species richness, which is associated with a shift in community composition and trophic group structure (Pearson & Rosenberg 1978; Tsutsumi 1990; Meksumpun & Meksumpun 1999; Coleman & Cook 2003; Rossi 2003). Changes in sedimentation rates lead to shifts in trophic groups, with the abundance of suspension feeders decreasing in more turbid waters.

Following nutrient enrichment, the population density of opportunistic deposit feeders usually increases dramatically, and macroinvertebrate communities typically become dominated by polychaetes (Pearson & Rosenberg 1978; Tsutsumi 1990; Meksumpun & Meksumpun 1999). These worms are characterised by their ability to respond rapidly to environmental change and are widely recognised as useful indicators of environmental health (Pearson & Rosenberg 1978; ANZECC & ARMCANZ 2000).

3.2 Fish

3.2.1 Commercial and Recreational Fisheries

A variety of commercial fisheries operate within Moreton Bay, to the east of the PDA. Bay, tiger, eastern-king, western-king, red-spot king and greasy prawns and Moreton Bay and Balmain bugs are targeted by the otter trawl fleet. Banana, tiger, school, eastern-king, greasy, bay and endeavour prawns, blue swimmer crabs are fished for by the beam trawlers. Mullet, garfish, flathead, dart, catfish, bream, trevally, luderick and jewfish are targeted by the net fishery. Snapper, shark, cod and Spanish, school and spotted mackerel are fished by the line fishery. The crab fishery targets mud, sand and three-spot crabs. A number of other species, including sea pike, golden trevally, black trevally, tarwhine, tailor, squid, whiting, scad, shovel-nose ray, silver biddies, tuna, emperor, kingfish, cod, catfish, pilchards, and John dory are caught on occasion by all fisheries (DPI&F 2007).

The sheltered waterways of southern Moreton Bay provide the most important area in south-east Queensland for recreational boating and fishing (Hegerl 1986). The geography of the area has also enabled it to develop as a convenient and comfortable destination for low intensity ‘family’ fishing, for ‘serious’ recreational fishing, and for competitive events. Catch data for recreational fishers is poor, however recent estimates put the annual recreational catch for Brisbane City residents at 8.1 M tonnes. Species of estuarine fish important to recreational fishers in Moreton Bay include: bream, whiting, flathead, tailor, sand crabs, mullet, snapper mackerel, cod, parrotfish, sweetlip, trevally, jewfish, dart, catfish, perch, luderick, coral trout, sole, emperor, squire, flounder, yellow tail and a number of penaeid prawns (Quinn et al. 1992; Roy Morgan Research 1999). However, the main species targeted are yellowfin bream, whiting, flathead, tailor, crabs and prawns (Quinn et al. 1992).

3.2.2 Habitats Important to Fish and Fisheries

Estuarine seascapes comprise a mosaic of different habitats, including seagrasses, mangroves, saltmarshes, oyster reefs and rubble banks, and un-vegetated sand and mudflats (Skilleter & Loneragan 2003). These habitats provide a range of ecological values and are important for the maintenance of fisheries resource, biodiversity and ecosystem services, often supporting a high abundance and diversity of fish and invertebrates (Beck et al. 2001). In addition to sustaining adult populations, which are harvested by inshore fisheries, many habitats are widely recognised for their role as 'nurseries' for juvenile fish, crabs and prawns, and their contribution to the productivity of offshore fisheries (Coles & Lee-Long 1985; Connolly 1994; Laegdsgaard & Johnson 1995; Halliday & Young 1996; West & King 1996; Blaber 1997; Butler et al. 1999; Beck et al. 2001). For example, adult mud crabs spawn off shore, post-larvae move into coastal waters, where they settle in association with seagrass meadows and adjacent sand bars, older juveniles typically move into narrow, mangrove-lined tidal waterways and adults move into larger channels and the open estuary (Hill et al. 1982).

Individual species of finfish, crustaceans and molluscs have particular habitat requirements, which may change through stages of growth and life cycle. Many economically important species (targeted by both recreational and commercial fishers) have a stage in their lifecycle dependent upon estuarine habitat, most commonly as post-larvae and juveniles. Habitat preferences of commercially and recreationally important species that may use the Toondah Harbour are summarised in Table 3.5.

3.2.3 Species of Conservation Significance

A number of seahorse, pipefish and pipehorse species that occur in southern Moreton Bay are listed marine species under the EPBC Act, and protected within Commonwealth Marine waters. However, they are not protected in the State waters of the Moreton Bay Marine Park or the PDA.

Other protected species of fish are highly unlikely to ever occur within the PDA of adjoin waters.

Table 3.5 Distribution and habitat preferences of some commercially and recreationally important fish species that use estuarine habitats, such as the Coomera River (Kailola et al. 1993; Zeller 1998).

Species	Common Name	Spawning	Eggs and larvae	Post larvae	Adults
Finfish					
Acanthopagrus australis	yellow-finned bream	surf bars (May to August)	estuarine waters – often associated with seagrass and mangroves (October to November)	estuarine and inshore waters	estuaries, ocean beaches and rocky shores
Chrysophryss auratus	snapper	deep offshore reefs (May to July)	coastal waters, seagrass beds	rock or coral reefs; seagrasses in bays and estuaries	subtidal rocky reefs
Platycephalus fuscus	dusky flathead	estuary mouths and nearshore sand bars (November to January)	estuarine waters	estuaries and ocean beaches	estuaries and open beaches
Mugil cephalus	sea mullet	offshore coastal waters (early winter)	coastal waters, estuaries (late winter)	tidal, brackish and freshwaters	estuaries and open beaches
Scomberomorus commerson	Spanish mackerel	GBR waters, coastal waters (August to December)	coastal waters	inshore waters and estuaries	continental shelf
Lutjanus argentimaculatus	mangrove jack	–	–	mangrove-lined estuaries	inshore coral reefs to deeps of 120 m
Pseudocaranx	silver trevally	–	–	estuaries, bays and	continental shelf

Species	Common Name	Spawning	Eggs and larvae	Post larvae	Adults
Girella tricuspidata	luderick	surf zone and estuary mouths	seagrass beds	mangrove-lined creeks and estuaries	estuaries, rocky reefs and inshore coastal waters (i.e. seagrass areas)
Prawns/Crabs					
Fenneropenaeus merguiensis	banana prawn	inshore waters	inshore waters	mud flats in mangrove-lined estuaries	turbid nearshore waters to a depth of 20 metres
Metapenaeus ensis	Endeavour prawn	inshore waters	inshore waters	seagrasses and algal beds in estuaries and inshore waters	inshore waters
Scylla serrata	mud crab	offshore waters	coastal waters	intertidal waters in mangrove-lined estuaries	subtidal waters in estuaries
Portunus pelagicus	sand crab	inshore waters and estuaries	inshore waters and estuaries	shallow estuaries, sand banks and seagrass beds	inshore waters
Molluscs					
Saccostrea commercialis	Sydney rock oyster	intertidal rocky substrates in estuaries and inshore waters	estuaries and inshore waters	intertidal rocky substrates of estuaries and inshore waters	intertidal rocky substrates of estuaries and inshore waters
Sepioteuthis lessoniana	northern calamari	estuaries and inshore marine waters	estuaries and inshore marine waters	estuaries and inshore marine waters	inshore and offshore marine waters

3.3 Turtle, Dolphin and Dugong

3.3.1 Turtles

All of Australia's six species of marine turtles occur in Moreton Bay. This includes resident populations of hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles, and seasonal and occasional sightings of the other species (Couper 1998). Sub-adult and adult green turtle are common in the region, particularly in the shallows. Green turtles feed extensively on seagrass beds; particularly those dominated by *H. ovalis*, *H. spinulosa* and *H. uninervis* and may also feed upon the fallen fruit of the grey mangrove (*Avicennia marina*) and algae (Col Limpus, Environmental Protection Agency, pers. comm.).

Loggerhead and hawksbill turtles are less common in Moreton Bay than the green turtle. They feed on crabs, other crustaceans, molluscs, sponges, jellyfish and fish. In Moreton Bay there are large populations of green and loggerhead turtles close to seagrass meadows along the western coast of Moreton and North Stradbroke Island (Couper 1998); particularly Moreton Banks, Amity Banks and Peel Island (QPWS 2001).

Moreton Bay is an important feeding ground for marine turtles – the long life-span of these reptiles (35 – 50 years to sexual maturity) and fidelity to feeding grounds (Couper 1998) means that turtles may rely heavily on the seagrass meadows in Moreton Bay. Historical evidence indicates that there were once large turtle populations in western parts of the bay; however, today their distribution is mostly confined to the eastern sections (Neil 1998).

Whilst boat traffic is likely to deter turtles of all species from the vicinity of Toondah Harbour, its likely that green turtle occasionally feed on the seagrasses within and adjoin the PDA. Turtles are occasionally subject to boat-strike in southern Moreton Bay.

3.3.2 Dolphins

Several species of dolphin are use southern Moreton Bay. These include inshore bottlenose dolphins (*Tursiops aduncus*) and the Indo-Pacific humpback dolphin (*Sousa chinensis*). Both these species are common, with approximately 300 to 500 bottlenose dolphins in the bay, and 100 humpback dolphins (Corkeron 1995). Irrawaddy river dolphins (*Orcaella brevirostris*) have also been sighted in Moreton Bay, but sightings are rare (Hale et al. 1998). Australian snub-nosed dolphins (*Orcaella heinsohni*) have a range inclusive of south-east Queensland, but due to the relatively recent discovery of this species, confirmed sightings within the region are rare.

Humpback dolphins eat fish associated with mangrove habitats and are consequently affected by disturbances to these habitats. Humpback dolphins seem to stay within a home range and females in particular are site specific. Bottlenose dolphins are also likely to use a home-range area, but their range does not overlap greatly with the range of humpback dolphin, as they feed more on species associated with reefs and sandy bottoms (Hale et al. 1998). Although (harbour) boat traffic is likely to deter dolphins, inshore bottlenose and Indo-Pacific humpback dolphins may occasionally feed over the tidal flats of Toondah Harbour.

3.3.3 Dugong

Moreton Bay is the southern limit of dugong distribution along Australia's east coast (Preen 1995). Approximately 800 to 900 dugongs live within the bay, feeding almost exclusively on the seagrass species *H. ovalis*, *H. spinulosa* and *H. uninervis* (Preen 1992; 1995; Lanyon & Morris 1997). However, they also feed on the seagrass, *Z. muelleri*, particularly when it is in flower (Conacher, pers. obs. 2006). In Moreton Bay, there is over 260 km^2 of dugong habitat, which supports one of the largest populations in Queensland (WBM & Sinclair Knight Merz 1995; Lanyon & Morris 1997 and references therein).

As dugong are long-lived animals, with a low reproduction rate and long generation time, they take a long time to rebuild a population after disaster (Marsh 1989). Dugong distribution within Moreton Bay, as with turtles, is now largely confined to areas adjacent to the South Passage Bar, due to a combination of habitat degradation (Neil 1998) and boat traffic (Preen 1992). Aerial surveys indicate that in most instances, the majority of Moreton Bay's dugong (80 – 98%) are found around the Moreton and Amity Banks seagrass beds (Lanyon & Morris 1997). Whilst dugong typically avoid areas of intense human activity, they may on occasion feed on the seagrasses in the vicinity of Toondah Harbour or transit the area. Dugong are infrequently subject to boat-strike in southern Moreton Bay.

Table 3.6 Marine mammals that may occur in Moreton Bay, and the likelihood that they are present in the vicinity of Toondah Harbour at any given time (DEWHA 2009).

Species	Common Name	EPBC Act	NCWR	IUCN Red List	Likelihood of Presence
Delphinidae					
Delphinus delphis	common dolphin	C		LR	Very low

Species	Common Name	EPBC Act	NCWR	IUCN Red List	Likelihood of Presence
Grampus griseus	Risso's dolphin	C		DD	Very low
Lagenorhynchus obscurus	dusky dolphin	M, C			Very low
Orcaella brevirostris	Irrawaddy dolphin	M, C	R	DD	Very low
Sousa chinesis	Indopacific humpback dolphin	M, C	R	DD	Moderate
Stenella attenuata	spotted dolphin	C		LR, cd	Very low
Tursiops aduncus	inshore (spotted) bottlenose dolphin	C		DD	Moderate
Tursipos truncatus	(offshore) bottlenose dolphin	C		DD	Very low
Dugongidae					
Dugong dugon	dugong	M, O	V	VU	Low

EPBC Act: E – endangered, V – vulnerable, M – migratory, O – marine, C – cetacean

NCWR: V – vulnerable, R – rare

IUCN Red List: EN – endangered, VU – vulnerable, LR – lower risk, cd – conservation dependent, nt – near threatened, DD – data deficient

Table 3.7 Conservationally significant marine reptiles that have been recorded from, or that may occur in, the vicinity of Toondah Harbour (DEWHA 2009).

Species	Common Name	EPBC Act	NCWR	IUCN Red List	Likelihood of Presence
Cheloniidae					
Caretta caretta	loggerhead turtle	E, M, O	E	EN	Low
Chelonia mydas	green turtle	V, M, O	V	EN	High
Lepidochelys olivacea	olive ridley turtle	E, M, O	E	EN	Very low
Dermochelyidae					
Dermochelys coriacea	leatherback turtle	V, M, O	E	EN	Very low

EPBC Act: E – endangered, V – vulnerable, M – migratory, O – marine

NCWR: E – endangered, V – vulnerable

IUCN Red List: EN – endangered, CE – critically endangered, LR – lower risk, DD – data deficient

4 A Preliminary Analysis of Impacts and the Sensitivity of Marine Plants and Animals

4.1 Basis for Consideration

The discussion of impacts presented here is preliminary, and based on a combination of professional experience gained working on similar projects and Walker Corporation's preliminary site layout plan (Figure 1.1), bulk earthworks strategy (Figure 4.1) and navigation channel widening (Figure 4.2), indicating extensive dredging and reclamation to support residential development and a marina. As detailed design and construction methods are yet to be finalised, the discussion of potential impacts is often generic. All earthworks excavation and filling operations associated with the proposed reclamation, with the exception of the dredged excavation of the Fision Channel, is to occur within a perimeter bund to minimise the release of turbid water and sediment to the surrounding environment.

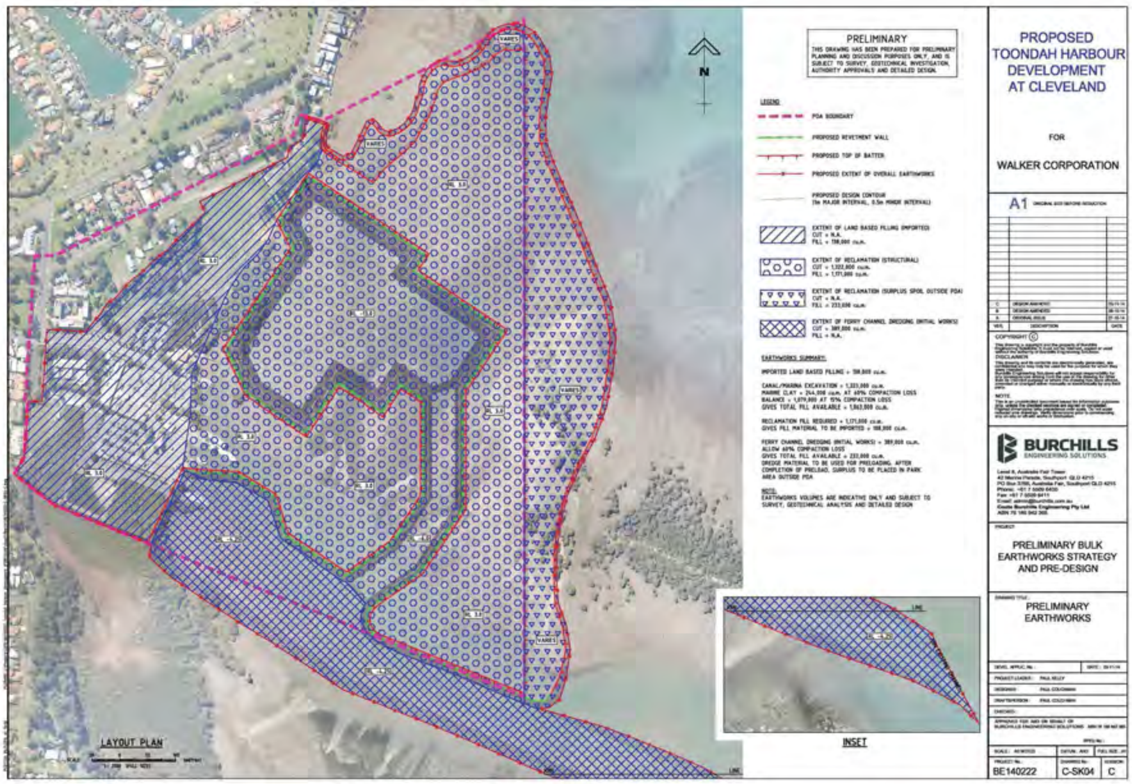


Figure 4.1 Preliminary bulk earthworks.

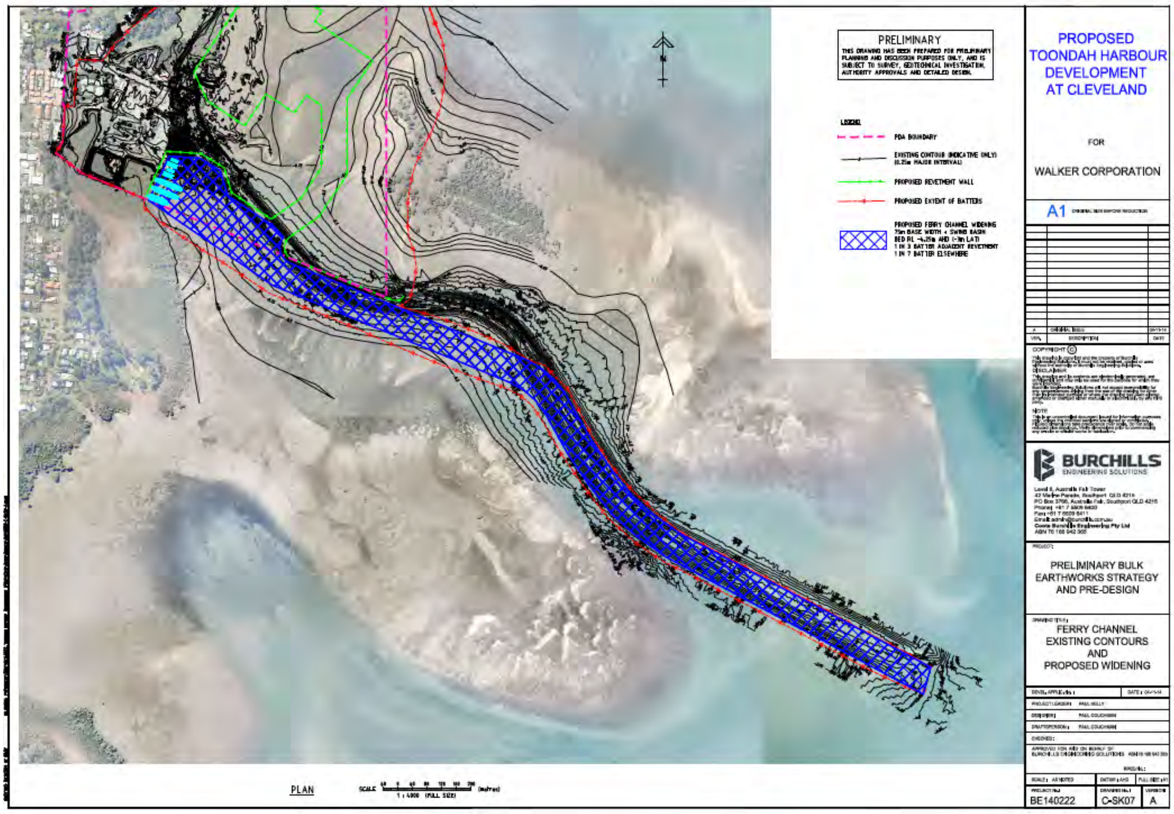


Figure 4.2 Preliminary navigation channel widening and re-alignment.

4.2 Analysis of Impacts

Table 4.1 presents a preliminary and generic analysis of potential impacts that may be associated with the proposed development of the Toondah Harbour PDA.

Table 4.1 Preliminary analysis of potential impacts on aquatic ecology.

Relevant Impact [a]	Extent of Impact	Unknown / Predictable	Reversible / Irreversible	Significance of Impact	Avoid / Minimise / Mitigation	Likelihood of Impact Occurring
Construction Phase						
Direct impacts during construction						
Loss of marine plants	Long-term	Predictable	Irreversible	High – impact on aquatic plants	Mitigate – fisheries offset	High
Loss of benthic habitat	Long-term	Predictable	Irreversible	Moderate – impact on small area	Mitigate – fisheries offset	High
Increased turbidity and sediment deposition; release of nutrients and other contaminants	Short-term	Predictable	Reversible	High – impact on moderate area	Minimize – dredging / excavation methods, silt curtains	Dependent on methods used Moderate
Change in community structure of benthic communities	Long-term	Predictable	Irreversible	Moderate – impact on small area		High
Gain of new marine habitat	Long-term	Predictable	Irreversible	Moderate – impact on small area	Mitigate – fisheries offset; Minimise – fish friendly structures	High
Fish trapped in wet	Short-term	Predictable	Reversible	High – impact on species of	Minimise – install silt curtains	Dependent

Relevant Impact [a]	Extent of Impact	Unknown / Predictable	Reversible / Irreversible	Significance of Impact	Avoid / Minimise / Mitigation	Likelihood of Impact Occurring
Loss of area for recreational fishes	Long-term	Predictable	Reversible	Low – small number of recreational fishers	Mitigate – offset with improved public access	High
Marine mammals and reptiles trapped in the wet excavation area by the silt curtain	Short-term	Predictable	Reversible	High – impact on species of conservation concern	Minimise – install silt curtains at low tide, spotters and cessation of work prior to and during construction	Dependent on methods used Low
Damage of marine mammals and reptiles by wet excavation	Short-term	Predictable	Reversible	High – impact on species of conservation concern	Minimise – install silt curtains at low tide, spotters and cessation of work prior to and during construction	Dependent on methods used Low
Disturbance of acid sulphate or potential acid sulphate sediment	Short-term	Predictable	Reversible	Moderate	Minimise – Acid Sulfate Soil Management Plan	High
Hydrocarbon contamination	Short-term	Predictable	Reversible	Moderate	Minimise –Environmental Management Plan	Low
Increase in human activity and noise	Short-term	Predictable	Irreversible	High – impact on species of conservation concern	Minimise – spotters and cessation of work prior to and during construction	Moderate
Operation Phase						
Increased boat traffic and access	Long-term	Predictable	Irreversible	High – impact on species of conservation concern	Minimise – speed restrictions and 'go slow' areas within Moreton Bay	High

Relevant Impact [a]	Extent of Impact	Unknown / Predictable	Reversible / Irreversible	Significance of Impact	Avoid / Minimise / Mitigation	Likelihood of Impact Occurring
Altered hydrodynamics	Long-term	Predictable	Irreversible	Moderate	Minimise – erosion and sediment control plans; Stormwater Management Plan	Low
Chronic hydrocarbon contamination	Long-term	Predictable	Reversible	High – impact on species of conservation concern and fisheries value	Minimise – Environmental Management Plan	Low
Contamination by heavy metals	Long-term	Predictable	Reversible	High – impact on species of conservation concern and fisheries value	Minimise – erosion and sediment control plans; Stormwater Management Plan	Low
Increased litter in the aquatic environment	Long-term	Predictable	Reversible	High – impact on species of conservation concern	Minimise – Stormwater Management Plan and education signs	Low
Introduction of pest species	Long-term	Predictable	Reversible	Moderate - impact on biodiversity	Minimise – Weed Management Strategy	Moderate
Cumulative impacts (increased boat traffic, exacerbating existing impacts)	Long-term	Predictable	Irreversible	High – impact on species of conservation concern and fisheries value	Minimise – speed restrictions and 'go slow' areas within Moreton Bay	High

4.3 Sensitivity of Flora and Fauna

4.3.1 Disturbance of Acid Sulfate or Potential Acid Sulfate Sediments

Investigation has shown sediments from Toondah Harbour to have potential acidity (frc environmental 2010). Disturbance of intertidal and marine sediments may expose acid sulfate soils to oxidising (acidifying) conditions. Acid sulfate materials are formed when pyrite in sediments is exposed to oxidation. Pyrite (FeS_2) is unstable in the presence of specialised bacteria and atmospheric oxygen, decomposing to the form ferrous iron and sulfuric acid.

The effects of acidification can be chronic or acute. The effects of chronic acidification on Australian estuarine biota, including fishes, is poorly understood; however, sudden acidification has been responsible for fish-kills, disease and other disturbances (Sammut et al. 1993). Chronic low-level acidity may reduce vigour and predispose marine biota to other diseases. Historical fluctuations in commercial finfish and prawn catches may be partially attributable to periods of increased acidity in estuarine waters (Leadbitter 1993).

Other environmental effects of oxidation of pyrite include: the dissolution of clay minerals and the release of soluble aluminium, which is highly toxic to gilled animals (including fish, molluscs and crustaceans) and aquatic plants; the release of soluble iron, also toxic to aquatic life in high concentration; and the oxidation of ferrous iron causing large decreases in dissolved oxygen.

4.3.2 Increased Suspended Solids Concentration and Sediment Deposition

The effects of increased suspended solids and sedimentation resulting from dredging / excavation and spoil handling are highly variable. The likelihood of increases in suspended sediments and of smothering are closely related to the characteristics of the sediment. Coarse sediments settle from the water column quickly and are unlikely to move away from the excavation site. Fine sediments remain suspended longer; may be carried further before settling, and consequently are more likely to smother marine organisms.

Seagrass and Macroalgae Communities

The temporary increase in turbidity associated with excavation and spoil handling typically reduce the penetration of light through the water column. Light availability, or specifically the duration of light intensity exceeding the photosynthetic light saturation point controls the depth distribution of seagrasses (Dennison & Alberte 1985; Dennison 1987; Abal & Dennison 1996). For example, on average 30% of surface light; a light attenuation co-efficient of less than $1.4m^{-1}$ and total suspended solids of less than 10 mg/L are required for the survival of *Zostera capricorni* (Abal & Dennison 1996; Longstaff et al. 1998). *H. ovalis* another common species in the area, has a particularly low tolerance to light deprivation caused by pulsed turbidity such as floods and dredging (Longstaff et al. 1998). However, *H. ovalis* can quickly recolonise areas due to its high growth rate and high seed production.

Availability of light also affects the productivity of seagrasses. Seagrass exposed to higher light intensity is more productive than seagrass in less intense light (Grice et al. 1996). Consequently, impacts associated with dredging may result in at least a temporary decrease in seagrasses productivity. Light also controls the population dynamics of macroalgae (Lukatelich & McComb 1986a; cited in Lavery & McComb 1991).

Soft Sediment Benthos

The fauna associated with soft sediment habitats is typically determined by the character of the sediment: its grain size and stability and with the presence or absence of seagrass. Grain size influences the ability of organisms to burrow, and the stability of 'permanent' burrows. Unstable sediments support less diverse benthic communities than those that are relatively stable. Resuspension of fine sediments can interfere with the feeding and respiration of benthic fauna.

Increases in the concentration of suspended solids may impact the respiration and feeding of a variety of taxa reducing abundance, species diversity and productivity. The deposition of fine sediment over existing substrate is likely to influence the community structure in favour of those species most able to cope with fine sediment substrate to the disadvantage of those less able. Filter feeding and gilled fauna are most likely to be affected. Whilst dredging may impact soft sediment invertebrate communities within the dredge plume, impacts are typically temporary and reversible.

Fishes

The effect of increased suspended solids concentration and sediment deposition on estuarine fish communities is typically negligible.

Although some fishes may avoid areas of high turbidity, areas of high turbidity may also be attractive to a range of fishes, particularly juveniles, as it confers a greater degree of protection from predators (Blaber & Blaber 1980).

4.3.3 Nutrient Enrichment

Mangroves and Saltmarsh

Increased nutrients can have positive impacts on the productivity of mangrove communities; commonly there is an increase in growth and productivity associated with low levels of nutrient enrichment (e.g. Onuf et al. 1977; Clough et al. 1983; McLaughlin 1987; Dunstan 1990). Available data suggests that nitrogen availability is limiting mangrove growth in south east Queensland waters, such as Moreton Bay (Dennison et al. 1998). However, as there was no increase in leaf turnover rates, the capacity of mangroves in Moreton Bay to convert dissolved nutrients to particulate nutrients via litter fall may be limited (Dennison et al. 1998). That is, increasing nutrients may lead to an initial increase in biomass of mangroves; however, this uptake may not be sustained. In northern Australia, leaf production increased with nitrogen fertilisation (Boto & Wellington 1983). It has been suggested that the response of mangrove forest to nutrient enrichment could be in two stages, with an initial increase in leaf production followed by an increased foliar nutrient concentration (Dennison et al. 1998).

Seagrass

Nutrients released from disturbed sediments may alter the community composition of floral and consequently faunal communities. Increased nutrient loads may to lead to an increase in phytoplankton densities, and consequently a reduction in water clarity and seagrass depth distribution (Dennison et al. 1993).

Moderate amounts of additional nutrients in the water column can also increase seagrass growth (McRoy & Helfferich 1980). However, as macroalgae are more efficient at absorbing nutrients from the water column than seagrasses or coral, higher levels of nutrient enrichment can lead to an increase in macroalgae growth at the expense of seagrass and coral (Wheeler & Weidner 1983; Zimmerman & Kremer 1986; Lapointe 1997; McCook 1999; Koop et al. 2001). Consequently, benthic macroalgae may overgrow and displace seagrass, whilst drift and epiphytic algae may physically shade seagrass and coral, reducing their growth and distribution (Twilley et al. 1985; Silberstein et al. 1986; Maier & Pregnall 1990; Tomasko & Lapointe 1991). Epiphytic algae may also reduce diffusive exchange of dissolved nutrients and gases at leaf surfaces (Twilley et al.

1985; Neckles et al. 1993). Acute nutrient enrichment may also stimulate the growth of mangrove and saltmarsh (Adam 1990; Adam 1995).

The trophic structure of benthic invertebrate communities often changes with increased nutrient levels, becoming dominated by small opportunistic deposit feeders. In eutrophic estuaries deposit feeding spionid and capetellid polychaete worms often tend to dominate benthic communities.

Macroalgae and Phytoplankton

Elevated nutrients can rapidly be taken up and stored by macroalgae and phytoplankton during pulsed discharge events (Furnas 2003). Phytoplankton is very abundant in coastal waterways and has high nutrient uptake rates. As a result, phytoplankton is commonly the principal flora assimilating nitrogen and phosphorus within coastal estuaries of southern Queensland.

Nutrients exported to or released within the coastal zone can significantly increase the productivity and competitive potential of some macroalgal species (Schaffelke & Klumpp 1998a; Schaffelke & Klumpp 1998b), with macroalgal cover often being significantly correlated with distance from rivers mouths and positively correlated with turbidity, chlorophyll-*a* and current speed (van Woesik et al. 1999).

Phytoplankton communities are sensitive indicators of nutrient enrichment. Increased nutrient availability has been linked with not only increased phytoplankton biomass, but also with a shift in the community composition of the phytoplankton. Whilst correlations between increased water column nutrient levels and increased phytoplankton abundance are common, phytoplankton assemblages can incorporate nutrients so rapidly that there is no apparent increase in nutrients in the water column. Phytoplankton has the ability to uptake nutrients in various forms, such as ammonium (the preferred form of N), nitrate, urea and phosphate (Dennison & Abal 1999).

The diatom-cyanobacteria fraction of the phytoplankton community is often the first to respond to increased nutrient availability (Parsons et al. 1978, cited in Hallegraeff 1996), consequently diatoms are typically associated with algal blooms in tropical and sub-tropical coastal waters. However, chronic elevations in available nutrients can result in pronounced shifts from high biomass microplankton communities dominated by diatoms, to highly productive pico-nanoplankton communities (Harding 1994).

Phytoplankton growth is primarily limited by light, nutrients (principally phosphorous and nitrogen) and temperature. However, other macronutrients such as silicate and micronutrients (vitamins, trace elements and chelators) are also important in controlling growth and community composition (Hallegraeff 1996).

The Ecosystem Health Monitoring Program administered by the Healthy Waterways Partnership investigated factors limiting phytoplankton growth in Moreton Bay and the surrounding river estuaries. Phytoplankton growth responses are substantially lower in Moreton Bay than in the river estuaries, due to a lower abundance of phytoplankton in the bay. Throughout Moreton Bay and the river estuaries nitrogen is the major nutrient limiting growth.

Benthic Microalgae

Benthic microalgae play an important role in sediment nutrient processes, and are hypothesised to be highly efficient at denitrification and the absorption of nutrients (Dennison et al. 1998).

However, turbidity limits benthic microalgae productivity – for example, in the turbid reaches of the Brisbane River, benthic microalgae concentrations are 0 – 20 mg/m^2, compared to concentrations of around 50 mg/m2 at some sites in Moreton Bay, where there is low turbidity and growth is not nutrient-limited (e.g. southern Pumicestone Passage) (Dennison & Abal 1999).

Increases in sediment organic and nutrient loads often lead to a reduction in community diversity and species richness, which is associated with a shift in community composition and trophic group structure (Pearson & Rosenberg 1978; Tsutsumi 1990; Meksumpun & Meksumpun 1999; Rossi 2003).

Population densities of opportunistic deposit feeders characteristically increase in areas impacted by organic enrichment and macro-invertebrate communities typically become dominated by polychaetes (Pearson & Rosenberg 1978; Tsutsumi 1990; Meksumpun & Meksumpun 1999). These worms are characterised by their ability to respond rapidly to environmental change and are widely recognised as useful indicators of environmental health (Pearson & Rosenberg 1978; ANZECC & ARMCANZ 2000). In particular the polychaete families Capitellidae and Spionidae have been identified as indicators that are sensitive to organic enrichment (Tsutsumi 1990; ANZECC & ARMCANZ 2000). The densities of capitellid polychaetes in environments with high nutrient and organic loads typically exceed 1000 individuals per m^2 (Tsutsumi 1990; Hutchings et al. 1993). Such densities are generally indicative of organic enrichment and are used as the trigger levels for ANZECC & ARMCANZ guidelines.

Many benthic macro-invertebrate species are metal sensitive and increased concentrations have been shown to affect benthic invertebrates at the population and community level (Morrisey et al. 1996; Ward & Hutchings 1996; Reish & Gerlinger 1997). Increases in the concentration of trace metals in estuarine sediments remove metal sensitive species and facilitates the explosion of polychaete populations, which can selectively exploit metal contaminated conditions (Ward & Hutchings 1996). Changes in community structure are usually accompanied by a reduction in the richness and diversity of benthic macro-invertebrate communities.

Nutrient enrichment increases the cycling of sulphur through the sediment. Under normal aerobic conditions, hydrogen sulphide (H_2S) and sulphuric acid (H_2SO_4) produced during sulphate (SO_4) reduction rapidly convert back to SO_4 and have little impact on macroinvertebrate communities (Edgar 2001). Similarly, H_2S is not usually a problem in most anaerobic sediments, because it is quickly bound to Fe to form pyrite and iron mono-sulphides. However, H_2S may become a problem when the Fe scavenging capacity of the sediments is exceeded, that is, where there are very high organic loadings. In heavily organically enriched environments with low dissolved oxygen, H_2S and H_2SO_4 concentrations can increase dramatically (Coleman & Cook 2003), and allow these poisonous compounds to build up in the sediment, and potentially negatively impact macro-invertebrate communities (Coleman & Cook 2003).

4.3.4 Low Dissolved Oxygen

Many species of fish become stressed when DO concentrations drop below 4 mg/L, and levels of < 2 mg/L are fatal to most species. Similarly, invertebrates of the bed and bank are impacted by low DO concentrations.

Conditions of low DO, high H_2S and low redox potentials usually occur simultaneously and their impacts on macroinvertebrate populations are difficult to separate in their effect on community structure (Wu 2002). Under these conditions there is often a reduction in the richness and diversity of macroinvertebrate communities, which is associated with a trophic shift toward deposit feeding taxa (Wu 2002; Coleman & Cook 2003).

4.3.5 Contamination by Heavy Metals

The absorption of heavy metals from solution occurs in plants and animals by passive diffusion across gradients created by adsorption at the surface, and by binding by constituents of the surface cells, body fluids, etc. An alternative pathway for animals is when metals are adsorbed onto or are present in food, and by the collection of particulate or colloidal metal by food gathering mechanisms. Depending upon the types and concentrations of heavy metals release, impacts could range from the reduction of reproductive capacity of some species to the mortality of aquatic flora and fauna. The effect of chronic heavy metal pollution is still largely unresolved, and effects depend on the interrelationships of many physical and chemical factors. Threshold concentrations of toxicants to ensure the protection of aquatic ecosystems have been developed by the Australian and New Zealand Environment and Conservation Council (ANZECC & ARMCANZ 2000).

Antifouling paints used on the exterior of boats often contain heavy metals, particularly copper, that can build up in marine organisms. In south-east Queensland, many anchorages have exceeded of the ANZECC/ARMCANZ trigger values for copper, with copper concentrations in the water column correlated with vessel numbers (Warnken et al. 2004). The proposed development may increase the concentration of heavy metals, particularly copper in the water. This risk is reduced where International and Australian standards relating to antifouling paints are followed (National Heritage Trust 2007).

Contaminants may also enter the aquatic environment from stormwater run-off from the proposed development site. The release of toxicants to the marina and surrounding waters will be minimised by treating stormwater (with water sensitive urban design techniques) to comply with local water quality criteria (Hyder 2010). Further, the sediment and erosion control plan is developed to minimise the release of sediment-bound toxicants to the water (Hyder 2010). With these in place, it is unlikely that suspended sediments and toxins become critically elevated in the waters of, and adjoining, the marina, and are therefore unlikely to cause an adverse ecological impact.

4.3.6 Acute and Chronic Hydrocarbon Contamination

Hydrocarbon spills from machinery during construction activities can negatively affect aquatic flora and fauna. It is possible that hydrocarbon spills could occur during the transportation of fuel or during equipment refuelling in the construction phase of the project. Concentrations of dissolved oil fractions below 0.01 ppm have not been shown to have adverse effects on any aquatic organism either in the short or long term, at any stage of development or at a cellular or sub-cellular level. Between 0.01 ppm and 0.1 ppm, some adult animals show sub-lethal behaviour and physiological disturbance, while developmental stages may show retarded growth or increased abnormalities. In general, the developmental stages of a species are far more susceptible than are adults, frequently by one or two orders of magnitude (Brown 1985).

Whilst acute (or at least a one off) contamination may result in severe ecological consequences, recovery is in most cases inevitable. In contrast, chronic contamination can result in the permanent (or at least for the duration of contamination) morbidity or localised extinction of flora and fauna. Chronic small spills, though probably influencing a lesser area, effectively prevent recovery and lead to cumulative impacts. Frequent spills from diffuse locations within a waterway can result in an enduring impact over a very wide area.

Chronic hydrocarbon pollution can result from the synergistic effects of small, frequent spills, these small scale spills are frequently associated with the refuelling of smaller crafts at marinas, other purpose built and ad hoc refuelling facilities and boat ramps (GBRMPA 1998; Cullen Grummitt & Roe Pty Ltd 2000). Marinas that support considerable activity, including pleasure boat marinas, boat repair facilities and commercial fishing operations have significantly higher levels of both aromatic and aliphatic hydrocarbons than estuaries seldom used by boats (Voudrias & Smith 1986). The small-scale spills commonly associated with small-scale refuelling operations are rarely reported or treated: the petrol, diesel or oils are left to disperse under natural conditions.

Floral communities and sessile faunal communities are most at risk from chronic hydrocarbon pollution. As these communities often form a critical component of habitat (providing structural complexity, shelter and often food), a permanent impact to these communities may have a consequentially widespread impact on the mobile components of the faunal community including fishes and crustaceans. Both petroleum and petroleum by-products are harmful to mangroves (Odum & Johannes 1975) causing mechanical damage by blocking the pores in the pneumatophores and effecting respiration, photosynthesis and translocation (Mackey & Smail 1995). Hydrocarbons are also known to cause reproductive disorders, immune deficiencies, tumours and cyst development in marine mammals and reptiles, especially when they are stressed (Schaffelke et al. 2001).

Low levels of petroleum hydrocarbons in the aquatic environment are adsorbed onto, or incorporated into, the sediments, where they may persist for years (Voudrias & Smith 1986; Pelletier et al. 1991). A large number of small-scale oil spills may lead to a significant increase in hydrocarbons over time, in effect resulting in a permanent impact. Mangrove sediments in particular may serve as long-term reservoirs for chronic contamination holding hydrocarbons for periods in excess of 5 years (Burns et al. 1994).

Where fuel storage and handling activities are undertaken in accordance with AS1940 (Storage and Handling of Flammable and Combustible Liquids – encompassing spill containment and response protocols), the risk of impacts to aquatic flora and fauna due to chronic and acute fuel spills is considered minor.

4.3.7 Increased Litter in the Marine Environment

Seven turtles in Moreton Bay were found to have ingested synthetic materials in 2001, and nine turtles in 2002 (Greenland et al. 2004). Of these, most had ingested fishing line, and only two animals were released alive (Greenland et al. 2004). In 2001 and 2002, entanglement in fishing ropes / lines, bags and ghost nets accounted for 21-35% of the annual human-induced turtle stranding or deaths (Greenland et al. 2004).

Dugongs have also been stranded / killed by ingesting fishing line or hooks (e.g. 2 individuals in Moreton Bay in 2003), or becoming entangled in ropes, fishing line and crab pots etc. (0-2 individual each year) (Greenland & Limpus 2005).

4.3.8 Increase in Human Activity and Noise

Increased human activity during construction, including changes in underwater noise levels, may affect the behaviour of fauna, particularly marine mammals

Underwater noise and other loud sounds may affect marine mammals by interfering with their use of sounds in communication, especially in relation to navigation and reproduction (Weilgard 2007; Wright & Burgin 2007). Marine mammals cease feeding, resting or social interaction at the onset of acoustic disturbance and to initiate alertness or avoidance behaviours (Richardson et al. 1995). Marine mammals in the vicinity of frequent, high intensity noise are likely to be highly stressed or even physically harmed and consequently, are likely to stay well away from continuously operating acoustic disturbance (Smith 1997). Therefore, any Indo-Pacific humpback dolphins, bottlenose dolphins or dugongs in the vicinity of the proposed development may vacate the area on commencement of the proposed in-water works such as wet excavation. Noise from on-land works is unlikely to disturb marine mammals. Any avoidance behaviour is likely to cease following completion of the work

Turtles have relatively poor hearing and are far less likely to be impacted by underwater acoustic disturbance. In the unlikely event that in- and underwater construction does audibly disturb turtles, they may temporarily leave the area. Similarly, underwater construction noise may disturb some local fish, which may vacate the area for a short time.

4.3.9 Increased Boat Traffic

Increased boat traffic may increase the chance of collisions between boats and marine vertebrates, particularly turtles, both in the immediate vicinity of the proposed development and in the broader environs of the Marine Park.

Boat strikes are responsible for the largest proportion of all human-related turtle strandings or mortalities (Greenland et al. 2004). In general, the shallower the area and the larger the boat, the greater the risk of a boat strike to turtles. Turtles feed on the intertidal flats at high and mid tides, and drop into deeper waters (which can include the waters of navigation channels) at low tide, where they can be struck by passing traffic. This habit of moving into navigation channels increases the risk of boat strike.

Dolphins are likely to be able to avoid approaching boats; however, at least nine dolphins were killed in Queensland by boat strike in a period of 8 years (Greenland & Limpus 2007b). Dugong will also avoid approaching boats; however, they are slower than dolphins and more vulnerable to vessel strike. Since dugongs were included in the Marine Wildlife Stranding and Mortality Database in 1996, between 2 and 7 individuals have died each year due to boat strike (Greenland & Limpus 2007a). The majority of these boat strikes occurred in Moreton Bay due to the high amount of boat traffic. The vulnerability of dugongs (with slow breeding rates and slow maturity) means that any dugong deaths may contribute to a population decline.

Go slow areas in Moreton Bay Marine Park limit speed in areas that are recognised as particularly significant for dugongs and turtles.

4.3.10 Altered Hydrodynamics

Changes in water velocity around the proposed development may alter (increase or decrease) the suitability of habitat for marine plants as well as change the composition of benthic macroinvertebrates. Marine plants may be influenced by changes in velocity resulting in removal of sediment, changes in sediment composition and chemistry, as well as changes in turbidity levels. Benthic macroinvertebrate communities are also likely to change with any changes to water velocity: in low flow environments predators exert more influence on benthic community structure than in high flow environments (Leonard et al. 1998). Any changes to sediment grain size would also alter the composition of benthic macroinvertebrate communities.

Reduced velocities may result in an accumulation of fine sediment and may also result in changes to sediment chemistry and water turbidity. Marine plants are unlikely to be negatively impacted by reduced flows and may even show a positive response. The composition of benthic macroinvertebrates is likely to change due to lower water velocities in this area.

5 Survey and Laboratory Methods

5.1 Survey of Habitat

Surveys of habitat and associated flora and fauna were conducted from 5 to 6 November 2014. Habitats were assessed visually and differences in habitats were marked using a handheld GPS. The GPS waypoints were also compared to recent aerial imagery and then mapped. The entire PDA, including areas outside of the proposed boundary, were surveyed.

5.2 Description of Marine Plant Communities

Marine plant communities were classified according to the dominant species present and the relevant understorey or sub-dominant species present.

5.3 Condition of Marine Plant Communities

The marine plant communities were also qualitatively assessed for their relative value to aquatic ecology and fisheries. The abundance of crabs or crab burrows was used as an indicator of the ability of the site to support marine fauna. The availability of physical habitat for fauna, the amount of human or cattle disturbance, the ponding of water, and the relative proximity of each point to permanent water at low tide (to assess the likely frequency of tidal inundation) were also assessed. Categories used to describe the habitat value of marine plants to aquatic ecology and fisheries are described in Table 5.1 and Table 5.2.

Table 5.1 Categories used to qualitatively assess the value of marine plants excluding seagrass and macroalgae to aquatic ecology and fisheries.

Value	Criteria
Excellent	High abundance of fauna / crab burrows present, very complex structural habitat for fauna, likely to be regularly inundated
Very Good	High abundance of fauna / crab burrows present, complex structural habitat for fauna, likely to be regularly inundated, but some disturbance
Good	Some fauna / crab burrows present, periodical tidal inundation, some structural habitat for fauna provided, little anthropogenic disturbance
Fair	Low abundance of fauna / crab burrows, habitat is disturbed, little structural habitat provided to fauna, infrequent tidal inundation
Poor	Little to no fauna present, poorly flushed, little / no structural habitat provided to fauna, habitat is heavily disturbed, infrequent or no tidal inundation, only opportunistic species present

Table 5.2 Categories used to qualitatively assess the value of seagrass and macroalgae to aquatic ecology and fisheries.

Value	Criteria
Very good	High percent cover and biomass of seagrass, offering complex structural habitat for fauna, proximal to mangroves, high densities of fauna / crab burrows and no damage such as burning or discolouration
Good	Moderate percent cover and biomass of seagrass, offering good structural habitat, proximal to mangroves, moderate densities of fauna / crab burrows and little damage evident
Fair	Moderate percent cover and biomass of seagrass, offering some structural habitat, proximal to limited mangroves, some fauna / crab burrows and some damage evident
Poor	Low percent cover and biomass of seagrass, offering little structural habitat, distal to mangroves, few fauna / crab burrows and damage evident
Very poor	Very low percent cover and biomass of seagrass, offering very little structural habitat, distal to mangroves or mangroves absent, very few fauna / crab burrows with only opportunistic species present and extensive damage evident

5.3.1 Structural Elements

Structural elements, such as trees, seedlings, aerial roots and pneumatophores, provide habitat for marine organisms. Leaf litter on the forest floor, such as fallen mangrove leaves, and large debris (including dead tree trunks), also provide structural habitat in mangrove forests. However, very high cover of litter (> 50%) suggests that an area has a low frequency of tidal inundation and is poorly flushed, which reduces the fisheries value of the habitat.

Smaller structures, such as pneumatophores, seedlings and small aerial roots, provide habitat for certain species, while larger structures, such as tree trunks and large aerial roots, provide habitat for other species. The presence of structural elements with a range of different sizes provides heterogeneity of habitat, thereby offering a greater range of habitats to a larger number of different species of fish and crustaceans. That is, each structural element provides a degree of structural habitat, yet the presence of multiple structural elements provides structural heterogeneity and generally supports a more diverse community of marine organisms.

5.3.2 Abundance of Infauna

The abundance of infauna, such as crabs and molluscs, is a direct indicator of habitat use and food availability. Relative densities of crab burrows also provide an indication of use; however, the number of burrows does not necessarily equate to the number of individual crabs using the habitat, as some species create more than one burrow while others share burrows. Crabs and molluscs also provide food for fishes and large crustaceans.

Benthic Epi- and Infauna

Epifauna was visually observed at low tide in each habitat, except for the channel. Additionally, pitfall traps were set in mangrove habitats at low tide and remained in the sediment for one tidal cycle. After 24 hours (+/- 2 hrs) the pitfall traps were retrieved and fauna was identified and counted; and all fauna was returned to the environment.

Benthic infauna was assessed by taking three invertebrate cores at two sites from each habitat, except mangrove habitat (Map 2). Cores were collected using an Eyer's corer with a diameter of 10.5 cm to a depth of 30 cm. Samples were sieved in the field through a 500 µm sieve and preserved using ethanol solution. The samples were transported to the laboratory where they were stained with Rose Bengal and macroinvertebrates were picked, sorted and identified to the lowest taxonomic level, in most instances to family.

5.3.3 Data Analysis

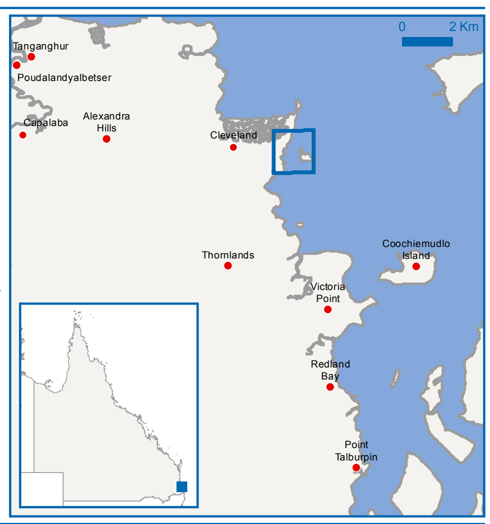
Means of abundance (total number of individuals) and taxonomic richness (family richness) were determined for each site.

Toondah Harbour PDA
Ecological Studies in Support of Works Area Determination

Map 2:
Macroinvertebrate sites surveyed

LEGEND

- Macroinvertebrate Sampling Site
- Toondah Harbour PDA
- Indicative Extent of Reclamation



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