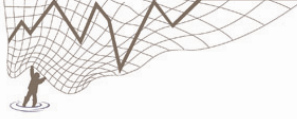




**Cardno
Ecology Lab**

Shaping the Future

Marine and Freshwater Studies



Proposed Koolewong Marina Development

Aquatic Ecology Assessment

Job Number: EL1011059

Prepared for ADW Johnston Pty Ltd



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Cover Image: 'The Boathouse' restaurant at the site of the proposed Koolewong Marina.
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Document Control

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Executive Summary

Cardno Ecology Lab was commissioned by ADW Johnson to prepare an aquatic ecology assessment in relation to the construction and operation of a 50 berth marina at Koolewong as an addition to the existing 'The Boathouse' restaurant and associated jetty. Koolewong is situated along the western shore of Brisbane Water, a relatively shallow and tidal northern arm of Broken Bay, just south of Gosford, NSW. The aim of this report is to provide an assessment of potential impacts on aquatic ecology at the site and surrounding area of the proposed Koolewong Marina development.

The proposal involves extending the existing jetty (approximately 30 m long) through the addition of a floating pontoon system reaching an additional 100 m into Brisbane Water. No changes are planned for the 16 piles of the existing jetty, however the deck area is to be widened by 0.5 m (from 1 m to 1.5 m) and the timber decking removed and replaced with a "seagrass friendly mesh". The proposed marina consists of a "reversed F" shape plan, with the outside arm being 124.5 m and the inner arm being approximately 80 m.

In considering the potential impacts of the proposed marina development at Koolewong, the occurrence of threatened and protected species, populations and ecological communities were assessed. Threatened or protected species listed under relevant schedules of the Commonwealth EPBC Act, NSW TSC Act and the FM Act) were identified using the EPBC Environmental Reporting Tool (DSEWPC 2011) and the DECCW Threatened Species Database (DECCW 2011). The proposal was not considered likely to affect any threatened species, population or ecological communities to the extent such that a species impact statement is recommended. Similarly, the proposed marina development at Koolewong is considered unlikely to have a significant impact on matters of NES and a referral to the Federal Minister under the EPBC Act would not be recommended.

Habitat mapping was done to determine what aquatic vegetation was present in the area surrounding the proposed Koolewong Marina development and the proximity of aquatic vegetation to the proposed development. The habitat mapping was initially undertaken on 28 July 2010 as part of a preliminary assessment of environmental risk of the proposed Koolewong Marina development. This mapping was extended on a site revisit on 31 August 2010 as a result of a reconfiguration of the proposed marina design. The mapping was verified during a site visit on 7 March 2011. Data collected were plotted onto a georectified drawing of the existing jetty and proposed marina structures using MapInfo Professional. Three species of seagrass were observed: *Posidonia australis*, *Zostera capricorni* and *Halophila* sp. The marine pest *Caulerpa taxifolia* was recorded near the end of the jetty and slightly offshore of the jetty. Several grey mangroves (*Avicennia marina*) were observed along the north-western and south-eastern shores on either side of the restaurant. The seagrass beds extended up to the edge of the existing jetty, and in some cases extending under the jetty footprint. No seagrass was observed under the footprint of the proposed marina extension, therefore no seagrass would be lost via direct displacement under the proposed marina extension.

Water and sediment chemistry in the vicinity of the proposed development seven sites were sampled on 7 March 2011. The data obtained were compared with ANZECC (2000) guidelines for the protection of aquatic ecosystems and compared statistically among sites and/or depths. Relatively low levels of contamination were recorded with only copper, zinc and phosphorus being elevated in some water samples and mercury being slightly elevated in the sediment samples.

The development of a marina at Koolewong has the potential to affect the local and surrounding aquatic environment through various processes. The potential risks are predominately to the seagrass habitat and include mobilisation of sediments and associated water quality changes, direct damage to seagrass due to boating activities, shading of

seafloor through marina structures and introduction or spread of *Caulerpa taxifolia*. The likely risk of impact is considered to be small if suitable mitigation measures are included in a plan for construction and ongoing operations. The main mitigation measures to be considered include:

- Control of boat speed and movements around the construction site and marina;
- The use of hollow steel piles, which disperse less sediment than traditional wooden piles,
- Minimising the widening of the existing jetty;
- Replacing the existing jetty boarding with seagrass friendly mesh;
- The use of silt curtains may be necessary to minimise the dispersal of sediment;
- Monitoring turbidity during construction ;
- Accidental spillages of fuels and oils during construction and ongoing operation should be contained within floating booms and cleaned up as soon as possible;
- Discharging sewage and bilge water directly into Brisbane Water should be prohibited during both construction and ongoing operations;
- No deploying of anchors within seagrass beds;
- Avoid navigating over seagrass, particularly in shallow areas;
- Information on the presence, identification and distribution of the pest algae *C. taxifolia* provided to the construction team and marina users and how to avoid aiding its spread;
- Boat owners should be educated about the environmental problems associated with use of copper-based anti-fouling paints; discouraged from *in-situ* cleaning of boat hulls that have been treated with copper paints and encouraged to switch to non-toxic anti-fouling paints;
- The potential for introduction of contaminants during on board washing of boats could be reduced by encouraging the use of environmentally friendly cleaning agents.

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Abbreviations

ANZECC	Australian and New Zealand Environment and Conservation Council
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CAMBA	China-Australia Migratory Bird Agreement
CEL	Cardno Ecology Lab
CLT	Cardno Lawson Treloar
CMA	Catchment Management Authority
DECCW	Department of Environment, Climate Change and Water (<i>Now Office of</i>
DEWHA	Department of Environment, Water, Heritage and the Arts
DGRs	Director-General's Requirements
DPI	Department of Primary Industries (Now DTIRIS)
DSEWPaC	Department of Sustainability, Environment, Water, Population and
DTIRIS	Department of Trade and Investment, regional Infrastructure and Services
EA	Environmental Assessment
EPBC Act	Environmental Protection and Biodiversity Conservation Act
FM Act	Fisheries Management Act
GIS	Geographic Information System
GPS	Global Positioning System
I&I	Industry and Investment (Now DTIRIS)
JAMBA	Japan-Australia Migratory Bird Agreement
KTPs	Key Threatening Processes
LGA	Local Government Area
NATA	National Association of Testing Authorities
NES	National Environmental Significance
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SIS	Species Impact Statement
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSC Act	Threatened Species Conservation Act

1 Introduction

1.1 Background and Aims

Cardno Ecology Lab was commissioned by ADW Johnson to prepare an aquatic ecology assessment in relation to the construction and operation of a 50 berth marina at Koolewong as an addition to the existing 'The Boathouse' restaurant and associated jetty. Koolewong is situated along the western shore of Brisbane Water, a relatively shallow and tidal northern arm of Broken Bay, just south of Gosford, NSW.

The proposal involves extending the existing jetty (approximately 30 m long) through the addition of a floating pontoon system reaching an additional 100 m into Brisbane Water. No changes are planned for the 16 piles of the existing jetty, however the deck area is to be widened by 0.5 m (from 1 m to 1.5 m) and the timber decking removed and replaced with a "seagrass friendly mesh". The proposed marina consists of a "reversed F" shape plan, with the outside arm being 124.5 m and the inner arm being approximately 80 m (Pers. Comm. Adam Crampton, ADW Johnson 2011).

The aim of this report is to provide an assessment of potential impacts on aquatic ecology at the site and surrounding area of the proposed Koolewong Marina development. This assessment will form part of the overall environmental assessment (EA) of the proposal. It will address (in whole or part) the following key issues identified in the Director-General's Requirements (DGRs) for the proposed development (NSW Planning dated 20/12/2011 supplied by ADW Johnson):

- Provide an aquatic flora and fauna assessment. Outline potential impacts from construction and operation, on aquatic flora and fauna, and their habitats, the potential introduction of marine pests and relevant measures to mitigate, rehabilitate or compensate (DGR point 4.1).
- Outline measures for the conservation of any existing wildlife corridor values and/or connective importance of any vegetation on the site. Address measures to protect and manage any riparian corridors and adjacent aquatic habitats (DGR point 4.2).
- Identify any contamination (estuarine water and sediment) on site and appropriate mitigation measures (DGR point 6.3).
- Assess impacts from construction and operation of the proposal on local aquaculture (i.e. oysters) and recreational fishing (DGR point 10.1).
- Address the potential impacts on commercial fishing grounds and popular recreational fishing sites (DGR point 15.1).

Specific requirements from government agencies (which are not directly nominated in the DGRs) are also addressed in this report including:

- Impacts to threatened species listed under the Fisheries Management Act 1994 including an Assessment of Significance under State and Commonwealth legislation (i.e. 7-part test) for seagrass (particularly *Posidonia australis*) and other threatened species, populations and communities (I&I, 9/12/2010, GCC, 9/12/2010).
- Impacts to water quality during all construction activities and from the ongoing use of the marina (I&I, 9/12/2010).
- Provision of photographs of the site at high and low tide (I&I, 9/12/2010)
- Assessment of substrate type (I&I, 9/12/2010).

1.2 Synthesis of Existing Information

Brisbane Water is a wave-dominated barrier estuary and tidal tributary of the Lower Hawkesbury River system. It covers an area of 27.2 km² and has a catchment area of 165 km², which is relatively small compared to the size of the waterway. Due to the relatively small size of the catchment, surface inflows have very little influence on water levels within the estuary (CLT 2008). A range of sediment types are present in the estuary from coarse sands to fine silts. The distribution of these materials is dependent on proximity to source of sediments (i.e. ocean sands or river inflows) as well as localised current and wave regimes which sort and distribute sediments. Sediment and water contamination have been identified as issues in the Brisbane Water estuary with two of the main sources of contamination being Narara and Erina Creeks (CLT 2008).

A variety of aquatic vegetation exists throughout the estuary including seagrass, mangroves and saltmarsh (Creese *et al.* 2009). The seagrass contained within the estuary include *Posidonia*, *Zostera* and *Halophila*. Based on the DPI mapping only *Posidonia* and *Halophila* exist in the vicinity of the proposed Koolewong Marina site. Mangrove stands are also common along foreshores throughout the estuary with a small stand recorded at the proposed Koolewong Marina site. Saltmarsh occurs in some large areas of Brisbane water including Pelican and Riley's Islands. No saltmarsh habitat is recorded in close proximity to the proposed Koolewong Marina site with the nearest being at Pelican Island approximately 0.75 kilometres away.

Brisbane Water is heavily used for both commercial and recreational activities. One indicator of this is the number of boating facilities present in the estuary: 43 public wharves, 1071 private moorings, 462 commercial moorings, and 5 marinas/commercial boat sheds (CLT 2008). The existing marinas and boat sheds are located at Ettalong Beach, Booker Bay, Gosford, Empire Bay and Hardy's Bay (CLT 2008).

Brisbane Water provides an important resource for recreational and commercial fishing as well as aquaculture. Brisbane Water is open to both commercial and recreational fishing with some limitations for certain types of fishing in some areas (Fisheries Management (General) Regulation 2010). Most forms of recreational fishing are allowed throughout Brisbane Water, with the main restriction being the prohibition of nets and traps (including lobster traps) throughout the estuary. Additional restrictions apply in some areas including a ban on taking of shell fish in the Saratoga area and prohibition on harvesting by digging in Cockle Creek. Similar restrictions apply to commercial fishing with an additional restriction on digging in the Ettalong area.

Brisbane Water is also an important estuary for the oyster industry and contains areas classified as priority oyster aquaculture areas. Priority oyster aquaculture areas were established by assessment of areas within estuaries in terms of their suitability for oyster aquaculture based on a number of criteria (NSW Oyster Industry 2006). The oyster industry is important to the economy of the Central Coast with estimates that it contributes approximately \$3.3 million to the region annually (CLT 2008).

2 Threatened Species, Populations and Ecological Communities

2.1 Relevant Legislation

In considering the potential impacts of the proposed marina development at Koolewong on threatened and protected species, populations and ecological communities, there are three main relevant Acts: the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act); the NSW *Threatened Species Conservation Act 1995* (TSC Act); and the NSW *Fisheries Management Act 1994* (FM Act).

The provisions of these Acts are summarised below:

Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is administered by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and aims to:

- provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (NES);
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;
- promote the conservation of biodiversity;
- provide for the protection and conservation of heritage.

In the aquatic environment, the Act lists the following matters of NES:

- nationally threatened species, ecological communities, critical habitats and KTPs (including marine species);
- migratory species;
- Ramsar wetlands of national significance and;
- Commonwealth marine areas (this extends from 3 to 200 nautical miles from the coast).

Under the EPBC Act, any action that will have, or is likely to have a significant impact on a matter of NES must be referred to the Australian Government Minister for a decision on whether assessment and approval is required under the EPBC Act. To assist proponents in determining whether an action is likely to have a significant impact on a matter of NES, DSEWPaC (formerly DEWHA) has developed Significant Impact Guidelines 1.1 (DEWHA 2009).

All species of migratory birds listed under Annexes of bilateral migratory bird agreements i.e. JAMBA (Japan-Australia Migratory Bird Agreement), CAMBA (China-Australia Migratory Bird Agreement) and ROKAMBA (Republic of Korea-Australia Migratory Bird Agreement) are protected as matters of NES under the EPBC Act.

The EPBC Act also provides for the identification and listing of Key Threatening Processes (KTPs). A KTP may be identified and listed if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

Threatened Species Conservation Act 1995 (TSC Act)

In NSW, the TSC Act (administered through the Office of Environment and Heritage, formally DECCW) includes provisions to declare threatened species, populations, ecological communities and Key Threatening Processes (KTPs). Species populations and communities identified as 'endangered' are listed in Schedule 1 of the TSC Act. Species populations and communities identified as 'critically endangered' are listed in Schedule 1A of the TSC Act and species populations and communities identified as 'vulnerable' are listed in Schedule 2 of the TSC Act. The TSC Act also lists 'KTPs' that may threaten the survival of those species, populations and ecological communities.

Marine birds, mammals and reptiles are included in Schedules of the TSC Act whereas all fish and marine vegetation are listed under the FM Act (see below). In addition, the TSC Act provides for the identification and listing of habitat that is critical to the survival of an endangered species, population or ecological community.

Fisheries Management Act 1994 (FM Act)

The FM Act seeks to conserve fish stocks, key fish habitats and threatened species, populations and ecological communities of fish and marine vegetation. Consistent with those objectives is the aim to ensure social, cultural and economic benefits to commercial, recreational and Aboriginal fisheries as well as the wider community of NSW.

Species populations and communities identified as 'endangered' are listed in Schedule 4 of the FM Act. Species populations and communities identified as 'critically endangered' are listed in Schedule 4A of the FM Act and species populations and communities identified as 'vulnerable' are listed in Schedule 5 of the FM Act. The FM Act also lists KTPs that may threaten the survival of those species, populations and ecological communities.

Part 2, Division 2, Section 19 of the FM Act allows for the Regulation to declare specified species as protected fish, although not currently declining, these fish must be protected so they do not become threatened in future. Provisions for the protection of aquatic habitats and aquatic reserves are included under Part 7 of the Act. In addition, Division 3 of the FM Act provides for the identification of habitat that is critical to the survival of an endangered species, population or ecological community.

Marine vegetation including seagrasses, mangroves and algae is also protected in NSW and a permit is required from NSW Department of Trade and Investment, regional Infrastructure and Services (DTIRIS formally I&I NSW, fisheries) to undertake works or activities that may harm them. State legislation requires that developments likely to have a significant effect on threatened species prepare a Species Impact Statement (SIS). To assist proponents in the process of determining whether a development is likely to have a significant impact on a threatened species, DTIRIS has developed the 'Assessment of Significance' guidelines (NSW DPI 2008).

2.2 Review Methodology

For the purposes of this assessment, 'threatened species' refers to any estuarine or coastal species, populations or ecological communities and their habitats as defined and listed under Schedules 4 or 5 of the FM Act, Schedules 1 or 2 of the TSC Act, or Subdivisions C or D of the EPBC Act. This assessment also includes any species of fish listed as protected under the FM Act.

In order to assess the potential impacts of the proposed marina on threatened and protected species, relevant State and Commonwealth threatened species databases were searched. Threatened or protected species listed under relevant schedules of the Commonwealth EPBC Act, NSW TSC Act and the FM Act) were identified using the EPBC Environmental Reporting Tool (DSEWPC 2011) and the DECCW Threatened Species Database (DECCW 2011). Searches were carried out in March 2011 for species of marine fish, mammals, reptiles, algae and seabirds. For searches using the EPBC Environmental Reporting Tool, the local government area of Gosford was identified as the most relevant to the Koolewong locality. Searches of the DECCW Threatened Species Database incorporated the Wyong sub-region of the Hunter/Central Rivers region, which includes the locality of Koolewong. These database records were used to produce a comprehensive list of all threatened and protected species, populations and communities that have previously been recorded within these search areas.

For the FM Act, TSC Act and EPBC Act to have relevance there must be a likelihood that one or more threatened species occur in or encroach upon the study area which could then be potentially impacted upon by the proposed Project.

Species listed under State legislation that may occur in the study area and have potential to be affected by the proposal were assessed under the NSW Assessment of Significance Guidelines (NSW DPI 2008). Note that species listed as 'protected' do not require assessment of significance under State legislation.

As the Commonwealth assessment guidelines accept assessments using the state assessment format, only species that were not already assessed under the NSW Assessment of Significance, were assessed under the EPBC Significant Impact Guidelines 1.1.

2.3 Database Searches

Database searches identified 16 species of marine mammals, 29 species of fish (including 22 species of seahorses and pipefish), five species of turtles, 69 species of birds (seabirds and shorebirds), two sand dune plants, one endangered population (the seagrass, *Posidonia australis*) and one endangered ecological community listed under the threatened species Schedules that occur within the Gosford LGA and Wyong CMA sub-region (Table 1).

2.3.1 Marine Mammals

The majority of the listed marine mammals live predominantly offshore and would be unlikely to enter the narrow channel entrance and main basin of Brisbane Water where the marina would be located at Koolewong. Some species e.g. southern right whales (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*) are frequently observed in adjacent coastal waters during their annual migrations along the NSW coast to breeding grounds in warmer waters but would be very unlikely to travel into Brisbane Water. Furthermore, there are no known resting breeding or calving areas within the region. The New Zealand fur-seal (*Arctocephalus forsteri*) and Australian fur-seal (*Arctocephalus pusillus doriferus*) are known to occasionally frequent adjacent coastal waters to forage and could also forage and/or rest within the estuary on occasion, however, these species have not been recorded within the estuary and would also be unlikely to occur there or take up residence there. The common dolphin (*Delphinus delphinus*) and bottlenose dolphin (*Tursiops truncatus*) may also travel into estuaries to forage, and may potentially occur in the study area, however, they would be transient and unlikely to be directly affected by the proposed development. Given the localised, relatively small scale of the proposed marina and the rare occurrence of dolphins and seals within the main basin of Brisbane Water, any impacts to these species would be unlikely. Furthermore as these animals are fast moving they would not be at risk of injury from interactions with boats.

2.3.2 Fish

The grey nurse shark (*Carcharias taurus*) typically occurs on shallow, coastal rocky reefs with sandy gutters within the reef matrix often the preferred microhabitat (Last and Stevens 1994). Although it is probable that grey nurse sharks would enter estuaries to forage on occasion there is no evidence to suggest that they depend on estuarine habitat in particular. Similarly, black cod (*Epinephelus daemeli*) are mostly found in caves and gutters in coastal areas and adults are highly territorial, usually adopting a cave as a core territory (I&I NSW 2009). Black cod have been observed by divers or caught by anglers in estuaries however the locations of these occurrences has generally been at the mouths of estuaries and involved juvenile fish, thus it would be unlikely that these species would occur as far up the estuary as Koolewong or over exposed soft sediments. The whale shark (*Rhincodon typus*) has a typically tropical distribution and would rarely occur in NSW waters. The green sawfish (*Pristis zijsron*) is presumed extinct with the last recorded sighting in NSW over thirty years ago at Yamba (northern NSW) and the species is therefore very unlikely to occur within the study area.

Great white sharks (*Carcharodon carcharias*) occur from cold temperate to tropical waters and generally frequent coastal waters, often close to shore. They also swim into bays and estuaries. The sharks do not appear to frequent specific habitats, although they may take up residence adjacent to rocky shores, particularly where seals or sea lions are present. There is no evidence to suggest that great white sharks depend on estuarine habitat in particular, but it is

probable that juvenile great white sharks would enter estuaries to forage on occasion (Environment Australia 2002). In the event that any of these species of fish were present within the estuary it would be unlikely that the construction or operation of the proposed marina would pose any significant threat to these species. Localised disturbance associated with the construction works such as noise, vibration, and potential increase in turbidity would have a negligible impact on these transient species.

2.3.3 Marine Turtles

Most turtle species are predominantly oceanic, particularly the hawksbill turtle (*Eretmochelys imbricata*), and leatherback turtle (*Dermochelys coriacea*), while the flatback turtle (*Natator depressus*) is a vagrant to NSW waters and typically confined to warmer tropical waters (Environment Australia 2003). Thus, these species are unlikely to be found in Brisbane Water estuary.

The loggerhead turtle (*Caretta caretta*) and green turtle (*Chelonia mydas*) are typical of tropical and subtropical waters of Australia, but are known to frequent the NSW coast and associated estuaries, where they feed or may establish populations near warm water outfalls (Environment Australia 2003). Both species are known to utilise seagrass habitat to forage, while undertaking reproductive migration to Queensland waters during the warmer months of the year to nest. Like many marine turtles, these two species have low fertility rates and are under threat from pollution and critical habitat loss among other issues (Environment Australia 2003). These relatively slow moving species may also be vulnerable to boat strike if there was a localised increased in boating activity.

2.3.4 Estuarine Birds

Of the listed birds, several have been recorded in the Brisbane Water estuary (Robinson 2006), many of which are also migratory (Table 1). These include several wading birds (curlews, oystercatchers, plovers, bitterns, godwits and sandpipers), diving birds such as terns and oceanic seabirds such as albatross, petrels and shearwaters. Two penguin species (Little penguin, *Eudyptula minor* and Fiordland penguin, *Eudyptes pacyrhynchus*) have also been sighted in Brisbane Water Estuary (Robinson 2006), however there are no known nearby populations. Many of the oceanic seabirds spend the majority of their lives at sea and it would be very unlikely for these species to be affected by the proposed marina development at Koolewong as there are no known nesting, roosting or breeding areas for these species in the study area. Only species likely to occur in estuarine habitats were therefore considered further in the assessment of significance. This included 12 species protected under the TSC Act and 23 species listed under the EPBC Act as 'migratory'.

2.3.5 Marine Vegetation

Sand spurge (*Chamaesyce psammogeton*) grows on fore-dunes and exposed headlands, while coast groundsel (*Senecio spathulatus*) is refined to primary dunes. Thus, both species of listed plants are unlikely to be found in the study area.

2.3.6 Ecological Communities

Saltmarsh is listed as an endangered ecological community in NSW and known to occur in the Brisbane Water Estuary (Bio-Analysis 2007), however an investigation undertaken for the current study and estuarine macrophyte maps produced by Creese *et al.* (2009) do not indicate the presence of saltmarsh in the vicinity of the proposed marina at Koolewong.

2.3.7 Endangered Populations

The seagrass *Posidonia australis* is listed as an endangered population in Brisbane Water under schedule 4 of the FM Act. Habitat maps of Brisbane water produced by I&I NSW (Creese *et al.* 2009) and a recent site inspection carried out by Cardno Ecology Lab indicate that *Posidonia* beds occur directly adjacent to where the proposed marina would be constructed,

although none occurs directly beneath where the proposed berths and pontoons would be located.

2.3.8 Protected Species

Estuary cod (*Epinephelus coioides*), giant Queensland grouper (*Epinephelus lanceolatus*) and 22 species of syngnathiformes (seahorses, seadragons, pipefish, pipehorses and seamoths) are listed as protected under the FM Act. Estuary cod generally occur in more tropical waters although may be found as far south as Sydney. Adults are often associated with rocky reef habitat in the lower reaches of estuaries and would be unlikely to be found within the study area, however, juveniles are more likely to be associated with soft sediments and seagrass beds and could therefore potentially be found in the study area.

Seahorses and pipefish regularly occur in seagrass habitat and it is likely that they inhabit the study area adjacent to where the proposed marina would be located. Note that species listed as 'protected' do not require an assessment of significance under the FM Act.

2.3.9 Key Threatening Processes

The only KTP listed under State and Commonwealth legislation relevant to the current proposal would be 'the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW' (FM Act). Boats can act as vectors for marine pests and algae which can be transported via anchor chains and fishing gear. The noxious algae *Caulerpa taxifolia* is of particular concern as it has been observed within the study area, is easily spread, can grow rapidly and may potentially out compete native seagrasses.

2.4 Assessments of Significance (7-part test)

Assessments of significance under State and Commonwealth legislation were carried out for species that may occur within the study area and have potential to be affected by the proposed marina development. Under the TSC/FM Act this applies to species, populations and communities listed as endangered, critically endangered and vulnerable, but does not apply to 'protected species'. Under the EPBC Act, this applies to species listed as extinct in the wild, critically endangered, endangered, vulnerable or migratory and also to ecological communities that are endangered or critically endangered. The following species and populations were assessed:

1. Reptiles

- Loggerhead turtle (*Caretta caretta*)
- Green turtle (*Chelonia mydas*)

2. Estuarine Birds

- Common sandpiper (*Actitis hypoleucos*)
- Great egret (*Ardea alba*)
- Cattle egret (*Ardea ibis*)
- Ruddy turnstone (*Arenaria interpres*)
- Sharp-tailed sandpiper (*Calidris acuminata*)
- Red knot (*Calidris canutus*)
- Curlew sandpiper (*Calidris ferruginea*)
- Red-necked stint (*Calidris ruficollis*)
- Great knot (*Calidris tenuirostris*)
- Double-banded plover (*Charadrius bicinctus*)
- Greater sand plover (*Charadrius leschenaultia*)
- Lesser sand plover (*Charadrius mongolus*)
- Latham's snipe (*Gallinago hardwickii*)
- Swinhoe's snipe (*Gallinago megala*)
- Pin-tailed snipe (*Gallinago stenura*)
- Sooty oystercatcher (*Haematopus fuliginosus*)

- Pied oystercatcher (*Haematopus longirostris*)
- Grey-tailed tattler (*Heteroscelus brevipes*)
- Black bittern (*Ixobrychus flavicollis*)
- Broad-billed sandpiper (*Limicola falcinellus*)
- Bar-tailed godwit (*Limosa lapponica*)
- Black-tailed godwit (*Limosa limosa*)
- Eastern curlew (*Numenius madagascariensis*)
- Little curlew (*Numenius minutus*)
- Whimbrel (*Numenius phaeopus*)
- Painted snipe (*Rostratula australis*)
- Common greenshank (*Tringa nebularia*)
- Marsh sandpiper (*Tringa stagnatilis*)
- Pacific golden plover (*Pluvialis fulva*)
- Grey plover (*Pluvialis squatarola*)
- Terek sandpiper (*Xenus cinereus*)
- White-bellied sea-eagle (*Haliaeetus leucogaster*)
- Little tern (*Sterna albifrons*)
- Osprey (*Pandion halieatus*)
- Caspian tern (*Sterna caspia*)
- Common tern (*Sterna hirundo*)

3. Endangered Population

- Strapweed (*Posidonia australis*)

The assessments of significance are provided in **Appendix 1** for assessment under the TSC/FM Act and **Appendix 2** for species assessed under the EPBC Act. Note that all estuarine birds and marine turtles were grouped together as the potential impacts would be similar.

2.5 Conclusions

Assessments of Significance (State Legislation)

Green and loggerhead turtles may occur within Brisbane Water on occasion. Potential impacts to marine turtles as a result of the proposed marina include increased risk of boat strike, impacts to seagrass habitat (an important food source and foraging habitat) and reduction in water quality. Boat strike is not, however, considered to be a current issue within Brisbane Water and would be mitigated through existing zoning of appropriate boat speeds within the estuary and around the proposed marina. Given the existing level of boating activity within Brisbane Water, the addition of the marina at Koolewong would be very unlikely to exacerbate the overall risk level. A construction management plan would be developed to control the impacts on surrounding seagrass habitat and manage turbidity levels. No significant impacts on marine turtles would therefore be expected.

Several species of estuarine bird (including waders, diving birds and raptors) have been recorded within the study area that could potentially be affected by the proposal. The construction and operation of the marina is not, however, considered likely to have an effect on the habitat utilised by these species, such that it would cause any observable alteration to their behaviour or habitat requirements.

Potential threats to the persistence of *Posidonia australis* meadows relevant to the proposal include physical damage (from boat propellers, anchors and moorings), spread of the invasive pest alga *Caulerpa taxifolia* and a reduction in water quality.

In order to mitigate any potential impacts a construction management plan should be implemented. As a minimum, areas of *Posidonia* and *Caulerpa taxifolia* should be clearly identified (in the construction management plan) and possibly marked with buoys to avoid disturbance. Where possible anchors and equipment should not be deployed in known *Caulerpa* affected areas and any equipment should be inspected before and after use to avoid the spread of *Caulerpa*. Any *Caulerpa* collected on gear should be removed, bagged disposed

of with general refuse in accordance with DPI recommendations (I&I NSW 2009). Silt curtains may need to be used around pile driving works to ensure suspended sediments are contained and water clarity of adjacent seagrass beds is maintained. With such measures in place, no impacts on the Brisbane Water population of *Posidonia* would be likely to occur.

The proposal is not, therefore, considered to affect any threatened species or population such that a species impact statement is recommended.

As seagrass would not be directly affected during the proposed construction or operation of the proposed marina at Koolewong, a permit to harm marine vegetation under Section 37 of the FM Act would not be required.

Assessment of Significance (Commonwealth Legislation)

It is not considered that the proposed marina at Koolewong would have a significant impact on migratory wading birds, diving birds or raptors protected under the EPBC Act. The proposal would not have any significant direct or indirect impacts on the habitat of these birds or result in invasive species that are harmful to wading birds becoming established in estuaries. Potential impacts during construction of the proposed marina would have a minimal short term impact on any migratory birds roosting or feeding in the area. There are no breeding or nesting areas known to occur within the study area. Based on this assessment the proposed marina development at Koolewong is considered unlikely to have a significant impact on matters of NES and a referral to the Federal Minister under the EPBC Act would not be recommended.

Other Listed and Protected Species

Juvenile estuary cod and syngnathids may occur within the study area. However, any potential disturbance to these species e.g. from noise, vibration or increased turbidity would be temporary and short term. It is likely that these species, if present, would temporarily relocate to nearby areas of similar seagrass and soft sediment habitat. Any impacts are therefore expected to be minor and short-term.

3 Field Studies

3.1 General Site Description

'The Boathouse' restaurant consists of a two story building and associated car park positioned directly on the waterfront of Koolewong (Plate 1). The site backs onto Brisbane Water Drive, the main road link between Gosford and Woy Woy. The site is enclosed by a protective rock wall which continues along Brisbane Water Drive. Stormwater drains are present on the both the north-western (Plate 2) and south-eastern rock walls of the complex. The restaurant also partially extends over the water where it is supported by concrete pylons. An existing 30 m jetty also forms part of the property (Plate 1) which is accessed regularly by the M.V. Lady Kendall II, a 200 passenger, 34 m (106 ft) long timber cruiser that runs tours of Brisbane Water.

The enclosing rock wall provides habitat for a variety of estuarine animals, particularly molluscs including Sydney rock oysters (*Sacostrea glomerata*) gold-mouthed conniwink (*Bembicium auratum*) and limpets (*Cellana tramoserica*, *Patelloida mimula*, *Siphonaria denticulata*) (Plates 3 and 4). The support pylons of the restaurant supported a dense growth of Sydney rock oysters (Plate 4) while the piles of the existing jetty had minimal cover of oysters and were covered mainly by various turfing and foliose alga.

The estuarine sediment is predominantly coarse grained and sandy in the inshore area transitioning to finer, silty sediments extending out from the end of the existing jetty.

During a site visit on 7 March 2011 a common white faced heron (*Egretta novaehollandiae*) was observed wading through the exposed seagrass beds to the south-east of the complex at low tide (Plate 5), and a Pied Cormorant (*Phalacrocorax varius*) was observed perching on the handrail of the existing jetty.

3.2 Habitat Mapping

3.2.1 Aims

Habitat mapping was required to determine what aquatic vegetation is present in the area surrounding the proposed Koolewong Marina development and the proximity of aquatic vegetation in relation to the development. The aims of the survey were to:

- Map marine vegetation, including seagrasses, in the vicinity of the current and proposed marina structures;
- Produce a GIS-based map incorporating the current and proposed structures and any nearby marine vegetation;
- Provide an assessment of any potential impacts to seagrass arising from the construction and operation of the proposed development;
- Provide recommendations for mitigating any potential impacts on the aquatic vegetation due the proposed development.

3.2.2 Methods

The habitat mapping was initially undertaken on 28 July 2010 as part of a preliminary assessment of environmental risk of the proposed Koolewong Marina development. This mapping was extended on a site revisit on 31 August 2010 as a result of a reconfiguration of the proposed marina design. The full environmental assessment of the proposed marina required a site visit to collect water and sediment quality data. The previous mapping was verified during the site visit on 7 March 2011. The mapping verification consisted of confirming the extent and classification of the various seagrass and other aquatic flora regions previously mapped. The survey area included the existing jetty structure and the intertidal and sub-tidal areas within 50 m of the current and proposed structures. Survey conditions were cloudy with showers for the July 2010 fieldwork and clear and sunny for the August 2010 and March 2011 fieldwork. Water visibility was approximately 3-4 m during all fieldwork. At the time of the survey the tide was

rising to a high of 1.3 m at 11:48 on 28 July 2010, rising to a high of 1.5 m at 14:22 on 31 August 2010 and rising to a high of 1.5 m at 12:47 on 7 March 2011 (NTC 2011).

The marine vegetation in the survey area was observed using snorkel. Data on the composition, density and morphological characteristics of seagrasses and other marine vegetation were relayed to a second team member onboard a small punt. Measurements of the distance between the existing structure and seagrass beds were taken using a 30 m tape and positions were marked using handheld GPS (Garmin 24 channel, WGS 84 datum, Zone 56), with accuracy on each occasion of 5-6 m. Species of seagrass present and a qualitative estimate of density, patchiness and leaf length were also noted. In addition, notes were made describing the health of the seagrasses (i.e. epiphytic growth, physical damage from anchors or propellers etc.) within the study area. Depths were recorded at intervals along the outer edge of the seagrass bed using a handheld depth sounder. The data was used to determine the maximum and average depth of seagrass present. The averages were adjusted to AHD based on the time of sampling and the predicted tidal height.

Estimates of density were made by ranking each observation point using three categories as per King and Barclay (1986):

- 1 - low density (< 15% cover),
- 2 - medium density (15% - 50% cover), or
- 3 - high density (> 50% cover).

The level of patchiness was also estimated using three categories as per King and Barclay (1986):

- A – Individual strands or clumps,
- B – Patches up to 10 m diameter, or
- C – Beds of relatively even distribution.

Leaf length of seagrass was also categorised as follows:

- *Zostera* – S (short < 5 cm), M (medium 5 cm – 15 cm), L (long > 15 cm),
- *Posidonia* – S (short < 15 cm), M (medium 15 cm – 30 cm), L (long > 30 cm), or
- *Halophila* – S (short < 1 cm), M (medium 1 cm – 3 cm), L (long > 3 cm).

Photos were taken of the subtidal habitats and the depths at *P. australis* bed edges were recorded using a digital depth sounder. The depth of the seaward extent of *P. australis* was recorded at six locations for each of the two large beds either side of the existing jetty and the mean maximum depth for each bed calculated.

Notes were also made of the presence of the pest algae, *C. taxifolia* and other species of marine flora and fauna.

GPS coordinates taken during the survey were plotted onto a georectified drawing of the existing jetty and proposed marina structures (ADW Johnson 2010) using MapInfo Professional (version 10.5). The boundaries of seagrasses and marine vegetation containing similar species, densities, leaf lengths and patchiness were drawn according to the information gathered.

3.2.3 Results

During the site revisit on 7 March 2011 the verification of previous mapping indicated that the composition and extent of seagrass beds and mangrove habitat remained largely unchanged since the earlier surveys. The principle change occurred to the area occupied by the invasive algae *Caulerpa taxifolia*. The previous mapping found *C. taxifolia* to be present to the south-east of pile 6, extending under the jetty between piles 5 and 6. A small area of sparse *C. taxifolia* was also observed approximately 10 m seaward (north-east) of the existing jetty. These areas appear to have expanded in the March survey with *C. taxifolia* spreading from under the jetty to the north-western side of the jetty to about 2-3m from the jetty (Figure 1, Plate 6). The newly colonised area on the north-west of the jetty only contains minimal amounts of *C. taxifolia*. The patch recorded off the end of the existing jetty also appears to cover a more extensive area than

previously mapped. The patch appears to have spread to the south east and into deeper water to the north-east. The actual area of this *C. taxifolia* was difficult to map accurately due very sparse cover in this area.

Since the remaining seagrass areas remained essentially unchanged during the current survey no alterations were made to their mapped area (Figure 1). The following description is also consistent with earlier reporting (CEL 2010).

Three species of seagrass were observed: *Posidonia australis*, *Zostera capricorni* and *Halophila* sp. (Figure 1, Plate 7). The dominant species was *P. australis*, which was present in two separate beds, one either side of the jetty. Both these beds consisted of long leaved, dense and continuous seagrass (Pos3CL). The north-western bed was approximately 30 m wide and bordered *Z. capricorni* approximately 8 m from the shore (Plate 8). The eastern bed was approximately 50 m wide and bordered *Z. capricorni* approximately 40 m from the shore. The north-western bed was nearer the jetty than the eastern (0.5 m compared to 3 m). Two isolated patches of *P. australis* (< 1 m²) were also present to the west of the south-eastern bed (Pos3AL) (not presented on Figure 1 due to small size).

The mean maximum depth of the seaward extent of *P. australis* was as follows:

- North-western bed: -1.4 m AHD (Standard Error = 0.04), with a maximum recorded depth of -1.5 m AHD;
- South-eastern bed: -1.8 m AHD (Standard Error = 0.08), with a maximum recorded depth of -2.0 m AHD.

Z. capricorni occurred in two continuous beds situated between the *P. australis* and the shoreline. These were separated directly in front of the boathouse building by an area of unvegetated sediment. The north-western bed was long-leaved and dense (Zos3CL), while the south-eastern bed was comprised of two distinct areas, the outer bed was dense with long leaves (Zos3CL), the inner bed was also dense but with much shorter leaves (Zos3CS). Both these beds extended under the boathouse building where it overhangs the water. *Z. capricorni* also continued underneath the jetty close to the shoreline under a section of jetty where boards have been replaced with seagrass friendly mesh. A third bed of *Z. capricorni* was present between the existing jetty and the south-eastern *P. australis* bed (Zos2BM) and a small patch of *Halophila* sp. (< 0.5m²) was also observed to the east of the jetty adjacent to pile 7 (counting from the shore) (Hal1AS, not presented on Figure 1 due to small size). A moderate degree of epiphytic growth was present on the leaves of each seagrass species. There was no obvious damage, such as propeller scars, to the seagrass due to boating activities.

Several grey mangroves (*Avicennia marina*) were observed along the north-western (Plate 9) and south-eastern (Plate 10) shores either side of the restaurant. Along the south-eastern shore, *A. marina* pneumatophores (aerial roots) extended approximately 4-10 m seaward before merging with seagrass wrack and finally *Z. capricorni*. Along the north-western shore much fewer mangroves were present and only a small number of pneumatophores were visible although a large amount of wrack was present just inshore of the *Z. capricorni* (Plate 8).

3.2.4 Conclusions

The seagrass beds were found to be growing up to the edge of the existing jetty and in some places extended under the jetty footprint. On the north-western side of the jetty the *P. australis* bed grew up to 0.5 m from the edge of the existing jetty, while on the south-eastern side of the jetty the *P. australis* bed was separated from the jetty by approximately 3 m. *Z. capricorni* was found growing up to the edge of the existing jetty on both sides.

No seagrass was observed under the footprint of the proposed marina extension, therefore no seagrass would be lost via direct displacement under the proposed marina structures. The distance between the proposed structure and the nearest *P. australis* was approximately 7 m (from the southern corner of the proposal to the eastern *P. australis* bed).

The introduced pest algae *C. taxifolia* was found under and off the end of the existing jetty which would be within the footprint of the proposed marina. This requires consideration in terms

of the construction and operation of the marina to ensure that *C. taxifolia* is not inadvertently spread within the marina area and elsewhere in Brisbane Water.

3.3 Water and Sediment Quality

3.3.1 Aims

Limited existing data on water or sediment chemistry were found for the area of the proposed marina upgrade. A study was therefore implemented to provide data on the chemical properties of the water and sediments to assist with the assessment of the potential impacts associated with the proposed development. The basic aim of this study component was to characterise water and sediment chemistry in the vicinity of the proposed development. The study was undertaken as a “snapshot survey” which has limitations because it does not measure variability in parameters of interest through time. Notwithstanding this, the data provide some basis for assessment when considered in the context of other data for Brisbane Water and in relation to water quality guidelines (ANZECC 2000). These data can also contribute to a baseline for monitoring if the proposed development is approved.

3.3.2 Methods

Seven sites were sampled from a small, outboard-powered boat on 7 March 2011 (Figure 2, Appendix 3). Six of the sites were in the vicinity of the existing boathouse and proposed marina upgrade. These included two sites (S1 & S7) adjacent to stormwater outlets, a site at the end of the existing walkway (S2) and three sites (S3, S4 & S5) in the area of the upgrade. Site 6 was located on the opposite side of the bay near an area of oyster farming.

At each site a water quality probe was used to measure water temperature (°C), salinity (ppt), pH (pH units), dissolved oxygen (mg/L and % saturation), redox potential (ORP) and turbidity (ntu). Two measures (“replicates”) were taken at both the water surface and just above the seabed at each site and data were recorded on waterproof paper. The probe (Yeokal 211) was calibrated on the day prior to the field work.

At all sites except S6 two samples of surface water were collected for chemical analysis. Variables analysed were BTEX compounds (benzene, toluene, ethyl benzene, xylene), Total Petroleum Hydrocarbons (TPH), trace metals (antimony, arsenic, cadmium, chromium, copper, lead, nickel) and nutrients (total nitrogen and total phosphorus). Samples were collected in pre-washed containers supplied by the NATA-registered analytical laboratory (National Measurement Institute) and stored on ice. The samples were delivered to the laboratory accompanied by chain-of-custody forms. In addition, two samples of sediment from all sites (except S6) were carefully scooped into containers by divers, stored on ice and dispatched to the laboratory with a chain of custody form. The sediments were analysed for particle size (size classes passing sieves > 75 µ) by NATA registered laboratory SGS Australia. The chemical analysis of sediments was done by the NATA registered laboratory National Measurement Institute and included BTEX, TPH, trace metals (same metals as for water, plus mercury) and total organic carbon (TOC).

The data obtained were compared with ANZECC (2000) guidelines for the protection of aquatic ecosystems and compared statistically among sites and depths (probe data) or among the six sites in the vicinity of the marina upgrade. The statistics program Primer with Permanova+ extension was used to evaluate spatial differences in the data (Anderson *et al.* 2008). Where site and/or depth effects were statistically significant, levels within treatments were compared using permutational t-tests.

3.3.3 Results and Conclusions

Water

The survey of water and sediment indicated relatively low levels of contamination within the area studied. Most of the measures taken *in situ* with the probe were within ANZECC (2000) guidelines (Table 2). Dissolved oxygen levels were all above the lower guideline, indicating well-mixed water. At Site 7 oxygen slightly exceeded the upper guideline, perhaps due to water turbulence in the shallow waters of this site. Turbidity was slightly elevated at Site 7 and in one of the bottom samples each at sites 5 & 6 (Table 2). Again, this may have been due to localised turbulence, but it is not indicative of any broad scale water quality problems within the area. Statistical analysis indicated significant differences among sites for all the variables analysed (Table 3, Figures 3 & 4, Appendix 4). In several cases variation among sites was dependent on the position of sampling in the water column, but the largest variation typically occurred between S1 and S7 in comparison with the other sites.

No BTEX, TPHs, Sb, Cd, Cr, Pb or Ni were detected in any of the water samples collected (Table 4, Appendix 5). One replicate sample from Site 1 (stormwater outlet) yielded a copper concentration just exceeding ANZECC (2000), whilst zinc was slightly elevated in one sample at Site 1 and in both samples at Site 3 (Table 4). Concentrations of nutrients were generally below ANZECC (2000) guidelines, the exception being a record of slightly elevated total phosphorus in one sample from Site 1 (Table 4).

Sufficient data were available for statistical analysis of only four water quality variables. All but total phosphorus (TP) were non-significant, for TP the result was ambiguous due to a small number of available permutations (Table 5), but with a possible trend toward greater concentrations, on average, at the stormwater outlets (S1 & S7) compared to the outer parts of the waterway (Table 4).

Sediments

Sediment grain size showed a clear difference between the shallower samples taken near the stormwater outlets (S1 and S7) and the end of the existing jetty (S2) and the deeper waters of the study area (S3-5), with a much greater proportion of fines (and less sand) in the deeper areas (Figure 5 & Appendix 6). BTEX, TPHs and Cd were not detected in any of the sediment samples; Hg slightly exceeded the low-threshold for ANZECC (2000) sediment quality guidelines while none of the other metals tested exceeded the guideline thresholds (Table 6, Appendix 7). Statistical analysis indicated statistically significant site differences for most variables analysed (excluding copper and nickel) (Table 7, Figure 6 & Appendix 8) with differences generally occurring between the shallow and deep sites.

4 Assessment of Impacts

4.1 Description of Features of Proposal Relevant to Aquatic Ecology

This aquatic ecology assessment the proposed construction and operation of a 50 berth marina at Koolewong is based on the following design, operational and construction components (Pers. Comm. Adam Crampton, ADW Johnson 2011).

- Increase in width of the existing timber jetty from 1 m to 1.5 m and replacement of the existing timber decking with a “seagrass friendly mesh”;
- The marina, extending approximately 100 metres into Brisbane Water (Murphy’s Bay) from the end of the existing timber jetty; would accommodate 50 vessels. Approximately 75 % power vessels and 25 % sail driven vessels with drafts between 1 – 2.2 m and a maximum anticipated vessel length of 22 m;
- The main walkway would be 2.4 metres wide, with two arms, in a “reverse F” formation;
- The proposed marina would be a floating pontoon held in place by a number of pylons constructed of hollow steel with a PVC sleeve and cap on top to exclude air. The pontoon would have rollers surrounding the pylon to allow the marina to rise and fall with the tide;
- Upgrade and reconfiguration of the existing car park to provide eleven (11) additional car parking spaces to the existing thirty three (33) spaces.

The proposal will not involve:

- Land reclamation or dredging;
- Alteration to existing jetty piles;
- Slipways for construction, repair, maintenance;
- Sale or hire of boats;
- Fuelling of boats;
- Sewage pump out services; or
- Launching or landing facilities.

The construction phase is expected to last approximately 12 weeks, weather permitting. This would involve the delivery of piles (approx. 31) to a public launch facility in Koolewong, and craning them onto a barge which will then transport and install the piles. The piles will be delivered in batches as required so as to avoid the need to stock pile them. This would be done from a loading and unloading facility used by the local oyster farming industry. Once the piles are in place, the pontoons would be delivered (probably to the same location), and towed into place. The pontoon would comprise between 12 – 19 sections, depending on the system chosen for use.

4.2 Potential Impacts

The development of a marina at Koolewong has the potential to affect the local and surrounding aquatic environment through various processes. The potential impacts of these processes are considered in the current section. Mitigation measures are provided in Section 5.

4.2.1 Mobilisation of sediments

The installation of piles for the marina facility has the potential to disturb the seafloor and mobilise sediments into the water column. The extent to which sediment is re-suspended and turbidity increases depends on the characteristics of the material being disturbed (e.g. size, density and quality), pile installation methods, the hydrodynamic regime at the disturbed sites and background suspended sediment and turbidity levels (Pennekamp and Quaak 1990). The sediment in deeper areas where the piles are to be installed is generally composed of fine silt, hence there is a potential for pile driving operations to mobilise surface sediment. The planned use of hollow steel piles is likely to substantially reduce the amount of sediment mobilised during installation, due to reduced sediment displacement. Any increases in suspended sediments and turbidity will generally be localised and temporary in nature, persisting only whilst

piles are inserted with any suspended sediment likely to be dispersed by tidal processes except during slack tides.

Sediment mobilisation can also occur indirectly due to boating movements which create shoreline erosion through boat wash or propeller action, if too close to the substrata (Cardno 2011). The boats accessing the proposed marina site during construction and operation have the potential to increase sediment mobilisation. Mobilisation of sediments due to boat propeller action, is unlikely to be an issue because of the depth of water where boats will be operating during constructions and ongoing operation of the marina.

Marina developments can also cause deposition of suspended sediments if water flow is reduced as a result of encountering the marina structure. Iannuzzi *et al.* (1996) discussed the tendency of some marinas to create a new quiescent environment favouring the deposition of fine grain (silty) sediments. Since fine, silty, sediment already dominates the proposed marina site, and the water current speeds of the area are not strong enough to enable significant sediment transport at the seabed (Cardno 2011), it is unlikely that the sediment composition will change at the site due to settling of suspended sediments.

Sediment mobilisation and associated water turbidity, has the potential to impact seagrass habitats and other primary producers including microscopic algae in the water column and micro and macroalgae on the seafloor, due to resulting light attenuation (decreased light available for photosynthesis) and sedimentation (sediment settling with potential to bury benthic primary producers). Ralph *et al.* (2006) state that reduced light over prolonged periods can lead to depletion of seagrass carbon reserves or, in cases of extreme light deprivation, a lack of photosynthetically-produced oxygen can lead to sediment anoxia and more rapid mortality. However, several studies have shown that seagrasses can survive for at least several weeks under low light conditions, or following sedimentation but that larger species (e.g. *Posidonia*) could survive much longer due to greater storage of reserves (Vermaat *et al.* 1997). This suggests seagrass is unlikely to be permanently affected by short term, localised increases in turbidity.

The levels of sediment mobilisation and associated environmental impacts can be minimised by implementation of suitable mitigation measures (Section 5.1.1).

4.2.2 Impacts to water and sediment quality

In addition to the potential effects of sediment mobilisation on water quality the construction and operation of marinas can impact water quality through other means. The re-suspension of sediments resulting from pile installation has the potential to release organic matter, nutrients and contaminants sequestered in both surface and deeper layers of the sediment. The current study has shown that levels of various contaminants were below ANZECC sediment quality guidelines except for mercury which slightly exceeded the guidelines. PAHs have a low solubility in water and a strong affinity for particulate matter and are therefore unlikely to be released into the water column in large concentrations. Heavy metals occur in dissolved, colloidal and particulate forms, but are generally more concentrated in sediments. Organisms, such as zooplankton and bivalve molluscs, that feed on suspended particulates are more likely to take up these contaminants than those that are exposed to their water-soluble phases. Algae and bivalves are more likely to accumulate these contaminants than fish and crustaceans, both of which have the enzymes necessary to metabolise, eliminate or sequester PAHs and heavy metals. Due to the minimal levels of seabed disturbance to be associated with the pile installation it is unlikely that the suspended sediments will substantially affect existing water quality conditions. Any impacts on water quality due to sediment mobilisation will be addressed through mitigation measures for the reduction of sediment mobilisation (Sections 5.1.1 and 5.2.1)

Boats using the marina could introduce various chemicals into the environment as a result of leaching of toxic components from anti-fouling paints applied to boat hulls, combustion of fuel in boat engines, accidental spillages of fuel, oils, bilge water and sewage, and onboard washing of boats. The use of copper-based anti-fouling paints is of particular concern, because a large number of boats moored within a confined area are likely to contribute significant amounts of copper to the water column over an extended period. The introduction of these products into

the environment may impact on the flora and fauna of the site and surrounding area. The increased concentration of boats in the area proposed for Koolewong Marina is likely to lead to an increase in contaminants in the sediment in the immediate vicinity. Overall any contamination of sediments that does occur is unlikely to have substantial negative environmental consequences due to the high levels of boating activity currently in Brisbane Water in general and in the immediate area around the proposed marina (including numerous swing moorings). The risk and extent of boat derived contamination can be reduced through basic control measures (Sections 5.1.2 and 5.2.2).

4.2.3 Damage to habitats (particularly seagrass)

Effects due to the Displacement by Marina Structures

The marine vegetation in the area of the proposed marina is dominated by the seagrass species *Posidonia australis* and *Zostera capricorni* and by the mangrove, *Avicennia marina*. No shore-based construction is planned that would result in the removal or damage to existing mangroves. The proximity of the seagrasses in relation to the proposed construction is the main consideration that determines the nature and magnitude of potential impacts. The seagrass beds are inshore of the existing jetty, with no seagrass seaward of this position. Hence no seagrass occurs within the planned footprint of the additional marina extension, and consequently there will be no direct loss, removal or fragmentation as a result of the proposal (i.e. through displacement for pile installation). Additionally, there is no risk of shading impact on seagrass within the planned marina extension footprint (See Section 4.2.2).

Effects of Marina Construction and Ongoing Operations

Boating activities have the potential to impact on seagrass habitats directly through damage and/ or removal of vegetation. The close proximity of seagrass to the proposed Koolewong Marina means that there is an increased potential for seagrass damage during construction and operations. This may occur due to boats inadvertently anchoring in the seagrass or driving through shallow seagrass areas. In these cases seagrass can be damaged and removed through anchor drag or propeller action (boat propellers cutting through seagrass). The increase in boat traffic associated with the marina construction and ongoing operation will increase the risk, with the greatest risk occurring during construction, when work vessels would be accessing the area regularly over an extended period. It is likely that these vessels will need to anchor. If anchoring is undertaken incorrectly, particularly in inshore areas, it is likely that damage could result to seagrass habitat. Additionally, if work vessels inadvertently drive into shallow areas during construction they may also damage seagrass.

Similar risks exist due to boat movements once the marina is in operation, however, the provision of berthing facilities (permanent or temporary) can reduce these effects as boats may be less likely to anchor. Provision of marina-based berthing facilities would also allow boats access to the shore without having to drive over shallow seagrass habitat. Damage to seagrass as a result of boating activities during construction and ongoing operations can be reduced by some simple mitigation methods (Sections 5.1.3 and 5.2.3).

4.2.4 Introduction or spread of marine pests

Marinas and associated boating activities have the potential to introduce or spread marine pests. In NSW estuaries the greatest problem is the spread of the invasive algae *Caulerpa taxifolia*, which is often retrieved on anchors or other gear then transported to a new location. Because the *C. taxifolia* is already present in the area of the proposed marina, the importance of its introduction by vessels during construction and operation of the marina is negated. However, there is a potential to spread *C. taxifolia* throughout the marina site, and away from the marina to unaffected areas. The spread of *C. taxifolia* is more likely during construction than ongoing operations because vessels are more likely to be anchoring during construction.

The hulls of vessels utilising the marina are an additional pathway for the introduction of non-native flora and fauna, including marine pests.

Spread of *C. taxifolia* and other marine pests can be limited by simple control mechanisms which should be in place as part of the construction and operational procedures (Sections 5.1.4 and 5.2.4)

4.2.5 Shading of the water column and substratum

Marina structures and pontoons shade the seafloor. Shading has the potential to reduce or eliminate aquatic vegetation, particularly seagrass (by reducing the light available for photosynthesis), where this vegetation occurs directly beneath or in close proximity to the footprint of a marina. . Since no seagrass occurs within the planned footprint of the marina extension, there is no risk of a shading impact on seagrass.

As part of the proposed marina the existing jetty is to be widened from 1 m to 1.5 m and the existing wooden walkway is to be replaced by "seagrass friendly mesh". The existing jetty is bordered by seagrass along its length with the closest point between *Posidonia australis* and the jetty being 0.5m on the north-western side. *Zostera capricorni* currently grows up to and under the existing jetty close to shore where the jetty walkway has previously been replaced with seagrass friendly mesh. The wider jetty will not directly cover the *P. australis* bed, however, in some areas *Z. capricorni* may be covered. The use of seagrass friendly mesh will also allow increased light penetration compared to that currently experienced. As a consequence there is unlikely to be an increase in shading effects on the existing seagrass, and it is not expected that the seagrass will be affected by the widening. Additionally, it is possible that seagrass may spread into the area previously shaded by the wooden jetty once there is an increase in light penetration.

Additional primary productivity comes from the photosynthetic activity of microscopic, floating algae and diatoms in the water column and on the surface of the seabed. The marina and boats moored will also shade the underlying water column and seafloor and reduce the amount of light available to these photosynthetic organisms. Any potential decrease in productivity from microscopic algae will be inconsequential given the vast areas of similar, soft sediment habitat, within Brisbane Water.

4.3 Species of Conservation Significance

4.3.1 Threatened Species, Populations and Ecological Communities

It is likely that green and loggerhead turtles may occur within Brisbane Water on occasion. Given the existing level of boating activity within Brisbane Water, the addition of the marina at Koolewong would be very unlikely to exacerbate the overall risk of boat strike. No species impact statement is recommended for any of the marine turtles.

Several birds, listed as threatened, have been recorded in the Brisbane Water Estuary (Robinson 2006), many of which are migratory. It is possible that many of these may on occasion visit the site of the proposed marina. Construction and operation of the marina is unlikely to cause any significant impacts on wading birds within the study area as no habitat important for nesting or feeding would be lost as a result of the development. Disturbance from noise or vibration during construction would be temporary and localised and at worst would result in birds moving to similar areas nearby. Furthermore, the area within the vicinity of the proposed marina is relatively sparse in terms of vegetation suitable for roosting habitat. No species impact statement is recommended for any of the wading birds.

The proposal would not result in any direct impacts to the Brisbane Water population of *Posidonia australis* such that a viable local population of the species is likely to be placed at risk of extinction. Any indirect impacts would be negligible and mitigated through the implementation of a construction management plan (Section 5.1). No significant impact on *P. australis* beds would be expected and no species impact statement is recommended.

4.3.2 Protected Species

Estuary cod (*Epinephelus coioides*), giant Queensland grouper (*Epinephelus lanceolatus*) and 22 species of syngnathiformes (seahorses, seadragons, pipefish, pipehorses and seamoths) are listed as protected under the FM Act. Estuary cod generally occur in more tropical waters although may be found as far south as Sydney. Adults are often associated with rocky reef habitat in the lower reaches of estuaries and would be unlikely to be found within the study area, however, juveniles are more likely to be associated with soft sediments and seagrass beds and could therefore potentially be found in the study area. Seahorses and pipefish regularly occur in seagrass habitat and it is likely that they inhabit the study area adjacent to where the proposed marina would be located.

Species listed as 'protected' do not require an assessment of significance under the FM Act. Since no seagrass habitat is likely to be lost under the current proposal it is unlikely that these protected species will be affected by the development.

4.3.3 Key Threatening Processes

The only KTP listed under State and Commonwealth legislation relevant to the current proposal would be 'the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW' (FM Act). Boats can act as vectors for marine pests and algae which can be transported via anchor chains and fishing gear. The noxious algae *Caulerpa taxifolia* is of particular concern as it has been observed within the study area, is easily spread, can grow rapidly and may potentially out compete native seagrasses. Since *C. taxifolia* already exists in the area of the proposed development its introduction to the site is not a significant issue. The potential for its spread around the site, and to be spread to other unaffected areas are risks that need to be addressed in terms of the construction and operational procedures.

4.4 Provision of Novel Habitat

The floating pontoons, piles and jetty forming the structure of the marina would provide artificial habitat for a variety of organisms, including macroalgae, invertebrates and fish (Glasby 1999; Connell 2000 and 2001). The presence of these structures has the potential to alter the distribution, diversity and abundance of organisms in the environment (Connell and Glasby 1999; People 2006). The infaunal assemblages that eventually develop in the soft sediments that accumulate below marinas are also likely to differ from those found at comparable sites without pontoons (Van Dolah *et al.* 1992; McGee *et al.* 1995; Lindegarth 2001). This could be due to a reduction in benthic primary productivity, increase in sedimentation of detritus and/or the attraction of greater numbers of predatory fish and crustaceans to artificial structures (Weston 1992; Davis *et al.* 1982).

Floating pontoons, piles and jetty may also serve as habitats for fish and pelagic invertebrates and may even attract fish away from surrounding natural habitats. Small-bodied species of fish, for example, may be attracted to piles and pontoons, because they provide shelter, protection from predators and/or food. Marina structures in Sydney Harbour and Pittwater have marked effects on the distribution and abundance of fish, with twice as many species occurring around piles than pontoons and nearby open water (Clynick 2008). The structure of the assemblages associated with pontoons and piles also differed from that in the open water, but differences in assemblages between pontoons and piles were found only at some marinas on some occasions. The dissimilarity between the assemblages in open water and around marina structures was due to large mobile species, such as yellowfin bream and yellowtail that moved between these habitats, and species, such as hula fish, stripey and immaculate damsels, that were abundant only around pontoons and piles.

4.5 Recreational Fishing, Commercial Fishing and Aquaculture

Brisbane Water is an important location for recreation and commercial fishing and aquaculture. Developments in estuaries have potential to reduce of fishing or aquaculture production by removing important habitat or contaminating water and sediments. Brisbane Water is an important estuary for the oyster industry and contains areas classified as priority oyster aquaculture areas (NSW Oyster Industry 2006). The closest identified priority oyster aquaculture area is over 200m from the proposed site (NSW Oyster Industry 2006). The *State Environmental Planning Policy No 62 - Sustainable Aquaculture (1979)* states that development consent may be refused if the proposed development adversely affects, impedes or is incompatible with current oyster aquaculture or areas identified as priority oyster aquaculture areas through limiting access to these areas or impacting on water quality and consequently oysters.

Deterioration in water quality (Section 4.2) can affect the survival of fish, shellfish and other organisms and in some instances can contaminate them so that they become unsuitable for human consumption. Given the mitigation measures recommended it is unlikely that the proposed marina at Koolewong would result in any prolonged or widespread changes to water and sediment quality in Brisbane Water (Sections 4.2, 5.1.2 and 5.2.2). The NSW oyster industry sustainable aquaculture strategy (NSW Oyster Industry 2006) presents guidelines for land and water use planning to which will contribute to the protection or improvement of water quality for oyster aquaculture. These guidelines identify marinas and vessel pump-out facilities as potential non-point sources of contamination. The guidelines specify that these facilities need to be carefully regulated to ensure potential contamination from ongoing operation of the marina is minimised. Additionally the provision of educational and advisory signs for recreational boating is identified as required to help ensure sanitary water quality. Given that there would only be a localised increase in turbidity associated with construction and that the additional boats housed at the proposed marina would not significantly increase the large number of vessels already moored and using Brisbane Water it is unlikely that the proposal would cause adverse impacts to recreation and commercial fishing or aquaculture either during construction or ongoing operation due to changes in water quality.

Aquaculture and recreational and commercial fishing can also be directly impacted by marinas if important fishing grounds or priority aquaculture areas are replaced by a development. Bare sediment is present under the planned marina footprint, which is common through the estuary, hence there would be no significant reduction in fish habitat and as a consequence no unique fishing grounds are likely to be lost to the proposal. The addition of the marina structure including piles and walkway will add potential fish habitat to the area, and as a consequence it is probable that there will be a localised increase in some recreationally important fish species (Section 4.4). Additionally no priority aquaculture areas will be lost to the development as none are identified at the site of the proposed development (NSW Oyster Industry 2006).

5 Mitigation of Impacts

5.1 Construction

If construction operations are managed inappropriately there is potential for negative environmental impacts, particularly to seagrass due to its close proximity to the construction site. The risk of damage can be easily reduced to very low levels by implementation of some basic mitigation methods. Such control measures should be provided in the construction management plan documentation. This documentation should outline how the construction stage is to occur and include key constraints on how operations are to proceed.

5.1.1 Mobilisation of sediments

Sediment mobilisation during construction can be minimised by the following measures:

- Enforcing a 'no wash' speed limit on vessels as they approach and move around the work site. This should form part of the construction management plan documentation. The majority of construction vessels are likely to be shallow drafted barges, and are unlikely to cause sediment to be mobilised due to propeller action, particularly if a 'no wash' speed limit is adhered to (Cardno 2011);
- Sediment mobilisation during pile installation will be reduced by the use of hollow steel piles, which displace less sediment than traditional wooden piles;
- The use of silt curtains may be necessary to minimise the dispersal of sediment. However, care must be taken to ensure that the installation and operation of silt curtains does not inadvertently damage seagrass (e.g. silt curtain based chain contacting nearby seagrass);
- Monitoring of water turbidity should be considered during the installation of piles, to ensure that no sustained or widespread increases in turbidity occur.

5.1.2 Impacts to water and sediment quality

Potential impacts on water quality during construction can be minimised by the following measures:

- Impacts on water quality due to sediment mobilisation can be mitigated through reduction in the amount of sediment mobilised during construction (Section 5.2.1);
- Accidental spillages of fuels and oils should be contained within floating booms and cleaned up as soon as possible to prevent weathering and subsequent deposition of heavy fractions;
- Construction teams should be prohibited from discharging sewage and bilge water directly into Brisbane Water and encouraged to remove oil from bilge water by using bilge removing pads.

5.1.3 Damage to habitats (particularly seagrass)

To minimise the potential for damage to seagrass habitats during marina installation the following measures can be included:

- Construction teams should be made aware of the presence and distribution of this environmentally sensitive area as part of the construction management plan documentation;
- The importance of seagrass habitat, and details on how and why to avoid damaging seagrass should be included;
- Construction teams should be prohibited from deploying anchors within seagrass due to the likelihood of causing damage;
- Construction teams should be made aware of the importance of avoiding navigating over seagrass, particularly in shallow areas. If movements over seagrass are necessary during construction then these should be done at high tide, while travelling slowly and ensuring that adequate clearance is maintained between seagrass and propellers;
- To ensure work vessels avoid seagrass habitat it is advisable to deploy marker buoys outside of seagrass beds to give better visual indication of their outer extent;

5.1.4 Introduction or spread of marine pests.

The risk of spreading *Caulerpa. taxifolia* around the construction site can be reduced to low level by the following measures:

- The construction management plan documentation should include information on the presence and distribution of *C. taxifolia* at the construction site (including maps);
- Information on why the spread of *C. taxifolia* is an environmental issue and how to avoid aiding its spread should also be provided;
- Construction teams should avoid deploying anchors or other equipment in areas of *C. taxifolia*;
- Where this is necessary for construction or if *C. taxifolia* is retrieved on equipment in other areas it should be disposed of with other general refuse at land based facilities.

5.2 Ongoing Presence and Operation

The operation of a marina at the proposed Koolewong site poses some environmental risks, including damage to seagrass if boating access and movements are managed inappropriately. The risk of such damage can be easily reduced to very low levels by implementation of some basic mitigation methods. Information should be disseminated to marina users informing them of requirements regarding access and movements around the marina. This information may best be presented in the form of signage at key points on the marina (such as at access gates).

5.2.1 Mobilisation of sediments

Mobilisation of sediments due to boats accessing the marina can be minimised by:

- Enforcing a 'no wash' speed limit for vessels as they approach and move around the marina. This should be included on signage around the marina. Based on the likely drafts of vessels intended for the marina there is unlikely to be a risk of sediment mobilisation due to propeller action, particularly if a 'no wash' speed limit is adhered to (Cardno 2011);
- Vessels with deeper drafts should be housed on the outer arm, to maintain greater vessel clearance from the seabed.

5.2.2 Impacts to water and sediment quality

The following mitigation measures can be implemented to reduce potential risk of water contamination from boats:

- Boat owners should be educated about the environmental problems associated with use of copper-based anti-fouling paints; discouraged from *in-situ* cleaning of boat hulls that have been treated with copper paints and encouraged to switch to non-toxic anti-fouling paints;
- Accidental spillages of fuels and oils should be contained within floating booms and cleaned up as soon as possible to prevent weathering and subsequent deposition of heavy fractions;
- The potential for introduction of contaminants during on board washing of boats could be reduced by encouraging the use of environmentally friendly cleaning agents (i.e. those that do not contain chlorine or phosphate-based ingredients);
- Boat owners should also be informed that the discharge of untreated sewage into navigable waters is prohibited and the discharge of treated sewage within 500m of aquaculture, bathing, mooring and anchoring areas, persons in the water, beaches and marinas is prohibited;
- Boat owners should be prohibited from discharging bilge water within Brisbane water and encouraged to remove oil from bilge water by using bilge removing pads
- The provision of a sewage pump-out facility should be considered to help mitigate any impacts arising from the disposal of sewage. Alternatively marina users should be advised of the location of existing pump-out facilities in Brisbane Water.

5.2.3 Damage to habitats (particularly seagrass)

To minimise the potential for damage to seagrass habitats due to the movement of boats accessing the marina the following measures can be implemented:

- Information (such as signage) provided to marina users on the presence and distribution of seagrass at the marina site (including maps). The importance of this environmentally sensitive area should be outlined and details on how and why to avoid damaging seagrass provided;
- Prohibition of anchor deployment within seagrass;
- Avoid navigation over seagrass beds, particularly shallow areas;
- Deployment of signage buoys along the outside edge of the seagrass beds or suitable alternative should be considered to create a 'vessel exclusion zone'.

5.2.4 Introduction or spread of marine pests.

To minimise the risk of *C. taxifolia* being spread around the marina site, or to other areas by the boats accessing the marina facility the following measures can be implemented:

- Information (such as signage) provided to marina users on the presence, identification and distribution of *C. taxifolia* at the marina site (including maps);
- Details on why the spread of *C. taxifolia* is an environmental issue and how to avoid aiding its spread should be included.

5.2.5 Shading of the water column and substratum

Shading effects of the jetty, pontoons and walkways can be mitigated by:

- Minimising the widening of the existing jetty;
- Replacing the existing jetty boarding with "seagrass friendly mesh";
- Keeping the length and width of floating structures to a minimum;
- Using mesh or similar material for floating structures to allow light penetration.

6 Acknowledgements

This report was written by Chris Roberts, Kate Reeds, Dr Marcus Lincoln Smith and David Cummings and reviewed by Dr Peggy O'Donnell and Theresa Dye. Fieldwork was done by Chris Roberts and Dan Pygas. Mapping was done by Dan Pygas. Statistical analyses and graphing was done by Dr Marcus Lincoln Smith.

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8 Tables

Table 1: Threatened and protected species recorded within the Gosford LGA and Wyong CMA sub-region.

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Table 1: Threatened and protected species recorded within the Gosford LGA and Wyong CMA sub-region as listed under the NSW *Fisheries Management Act* (FM Act), NSW *Threatened Species Conservation Act* (TSC Act) and the *Environment Protection and Biodiversity Conservation Act* (EPBC Act). PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= Conservation Dependant, M = migratory, L = listed, Cet = cetacean and P = protected. Source: NSW DECCW threatened species database and the EPBC environmental reporting tool (accessed March 2011). *Aquatic birds reported to occur in Brisbane Water Estuary identified by Robinson (2006). Note: All native birds, reptiles and mammals in NSW are protected by the *National Parks and Wildlife Act* (NP&W Act).

Scheduled Species	Common Name	Status under TSC/FM Act	Status under EPBC Act	Aquatic birds identified by Robinson (2006)*
1. Marine Mammals				
Cetaceans				
<i>Balaenoptera acutorostrata</i>	Dwarf minke whale	P	Cet	NA
<i>Balaenoptera musculus</i>	Blue whale	E	Cet, E, M	NA
<i>Balaenoptera bonaerensis</i>	Antarctic minke whale	P	Cet, M	NA
<i>Balaenoptera edeni</i>	Bryde's whale	P	Cet, M	NA
<i>Caperea marginata</i>	Pygmy right whale	P	Cet, M	NA
<i>Delphinus delphis</i>	Common dolphin	P	Cet	NA
<i>Eubalaena australis</i>	Southern right whale	V	Cet, E, M	NA
<i>Grampus griseus</i>	Risso's dolphin	P	Cet	NA
<i>Lagenorhynchus obscurus</i>	Dusky dolphin	P	Cet, M	NA
<i>Megaptera novaeangliae</i>	Humpback whale	V	Cet, V, M	NA
<i>Orcinus orca</i>	Killer whale	P	Cet, M	NA
<i>Stenella attenuata</i>	Spotted dolphin	P	Cet	NA
<i>Tursiops aduncus</i>	Long-beaked bottle nosed dolphin	P	Cet, M	NA
<i>Tursiops truncatus</i>	Bottlenose dolphin	P	Cet	NA
Pinnipeds				
<i>Arctocephalus forsteri</i>	New Zealand fur-seal	V	L	NA
<i>Arctocephalus pusillus doriferus</i>	Australian fur-seal	V	L	NA
2. Fish				
<i>Carcharias taurus</i> (East Coast)	Grey nurse shark	CE	CE	NA
<i>Carcharodon carcharias</i>	Great white shark	V	V, M	NA
<i>Epinephelus coioides</i>	Estuary cod	P		NA
<i>Epinephelus daemeli</i>	Black cod	V		NA
<i>Epinephelus lanceolatus</i>	Giant Queensland groper	P		NA
<i>Pristis zijsron</i>	Green sawfish	PE	V	NA
<i>Rhincodon typus</i>	Whale shark		M, V	NA
Pipefish (Sygnathiformes)				
<i>Acentronura tentaculata</i>	Hairy pygmy pipehorse	P	L	NA
<i>Festucalex cinctus</i>	Girdled pipefish	P	L	NA
<i>Filicampus tigris</i>	Tiger pipefish	P	L	NA
<i>Heraldia nocturna</i>	Upside-down pipefish	P	L	NA
<i>Hippichthys penicillus</i>	Beady pipefish	P	L	NA
<i>Hippocampus abdominalis</i>	Eastern potbelly seahorse	P	L	NA
<i>Hippocampus whitei</i>	White's seahorse	P	L	NA
<i>Histiogamphelus briggsii</i>	Briggs' crested pipefish	P	L	NA
<i>Lissocampus runa</i>	Javelin pipefish	P	L	NA
<i>Maroubra perserrata</i>	Sawtooth pipefish	P	L	NA
<i>Notiocampus ruber</i>	Red pipefish	P	L	NA
<i>Phyllopteryx taeniolatus</i>	Weedy seadragon	P	L	NA
<i>Solegnathus spinosissimus</i>	Spiny pipehorse	P	L	NA
<i>Solenostomus cyanopterus</i>	Blue-finned ghost pipefish	P	L	NA
<i>Solenostomus paegnius</i>	Rough-snout ghost pipefish	P	L	NA
<i>Solenostomus paradoxus</i>	Harlequin ghost pipefish	P	L	NA

Continued

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Table 1: Continued

Scheduled Species	Common Name	Status under TSC/FM Act	Status under EPBC Act	Aquatic birds identified by Robinson (2006)*
2. Fish Continued.				
<i>Stigmatopora argus</i>	Spotted pipefish	P	L	NA
<i>Stigmatopora nigra</i>	Wide-bodied pipefish	P	L	NA
<i>Syngnathoides biaculeatus</i>	Double-ended pipehorse	P	L	NA
<i>Trachyrhamphus bicoarctatus</i>	Short-tailed pipefish	P	L	NA
<i>Urocampus carinirostris</i>	Hairy pipefish	P	L	NA
<i>Vanacampus margaritifer</i>	Mother-of-pearl pipefish	P	L	NA
3. Marine Reptiles				
Marine Turtles				
<i>Caretta caretta</i>	Loggerhead turtle	E	E, M	NA
<i>Chelonia mydas</i>	Green turtle	V	V, M	NA
<i>Eretmochelys imbricata</i>	Hawksbill turtle	P	V, M	NA
<i>Natator depressus</i>	Flatback turtle	P	V, M	NA
<i>Dermochelys coriacea</i>	Leatherback turtle	V	E, M	NA
4. Aquatic birds				
Shorebirds				
<i>Actitis hypoleucos</i>	Common sandpiper		L, M	✓
<i>Ardea alba</i>	Great egret	P	L, M	
<i>Arenaria interpres</i>	Ruddy turnstone	P	L, M	✓
<i>Calidris acuminata</i>	Sharp-tailed sandpiper	P	L, M	✓
<i>Calidris canutus</i>	Red knot	P	L, M	✓
<i>Calidris ferruginea</i>	Curlew sandpiper	P	L, M	✓
<i>Calidris ruficollis</i>	Red-necked stint	P	L, M	✓
<i>Calidris tenuirostris</i>	Great knot	V	L, M	
<i>Charadrius bicinctus</i>	Double-banded plover	P	L, M	
<i>Charadrius leschenaultii</i>	Greater sand plover	V	L, M	
<i>Charadrius mongolus</i>	Lesser sand plover	V	L, M	✓
<i>Egretta garzetta</i>	Little egret	P	L	✓
<i>Gallinago hardwickii</i>	Latham's snipe	P	L, M	✓
<i>Gallinago megala</i>	Swinhoe's snipe	P	L, M	
<i>Gallinago stenura</i>	Pin-tailed snipe	P	L, M	
<i>Haematopus fuliginosus</i>	Sooty oystercatcher	V		✓
<i>Haematopus longirostris</i>	Pied oystercatcher	E		✓
<i>Heteroscelus brevipes</i>	Grey-tailed tattler	P	L, M	✓
<i>Himantopus himantopus</i>	Black-winged stilt	P	L	✓
<i>Ixobrychus flavicollis</i>	Black bittern	V		✓
<i>Limicola falcinellus</i>	Broad-billed sandpiper	V	L, M	✓
<i>Limosa lapponica</i>	Bar-tailed godwit	P	L, M	✓
<i>Limosa limosa</i>	Black-tailed godwit	V	L, M	✓
<i>Numenius madagascariensis</i>	Eastern curlew	P	L, M	✓
<i>Numenius minutus</i>	Little curlew	P	L, M	✓
<i>Numenius phaeopus</i>	Whimbrel	P	L, M	✓
<i>Nycticorax caledonicus</i>	Nankeen night heron	P	L	✓
<i>Pozana tabuensis</i>	Spotless crane	P	L	✓
<i>Rostratula australis</i>	Painted snipe	E	V, L	
<i>Threskiornis molucca</i>	Australian white ibis	P	L	✓
<i>Threskiornis spinicollis</i>	Straw-necked ibis	P	L	✓
<i>Tringa nebularia</i>	Common greenshank	P	L, M	✓
<i>Tringa stagnatilis</i>	Marsh sandpiper	P	L, M	✓
<i>Pluvialis fulva</i>	Pacific golden plover	P	L, M	✓
<i>Pluvialis squatarola</i>	Grey plover	P	L, M	✓
<i>Xenus cinereus</i>	Terek sandpiper	V	L, M	✓

Continued

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Table 1: Continued

Scheduled Species	Common Name	Status under TSC/FM Act	Status under EPBC Act	Aquatic birds identified by Robinson (2006)*
Seabirds				
<i>Accipiter fasciatus</i>	Brown goshawk	P	L	✓
<i>Calonectris leucomelas</i>	Streaked shearwater	P	L, M	
<i>Circus approximans</i>	Swamp harrier	P	L	✓
<i>Diomedea antipodensis</i>	Antipodean albatross	V	V, M	
<i>Diomedea gibsoni</i>	Gibsons albatross	V	V, M	
<i>Falco cenchroides</i>	Nankeen kestrel	P	L	✓
<i>Haliaeetus leucogaster</i>	White-bellied sea-eagle	P	L, M	✓
<i>Haliastur indus</i>	Brahminy kite	P	L	✓
<i>Haliastur sphenurus</i>	Whistling kite	P	L	✓
<i>Hieraetus morphnoides</i>	Little eagle	V		✓
<i>Larus novaehollandiae</i>	Silver gull	P	L	✓
<i>Macronectes giganteus</i>	Southern giant petrel	E	E, M	
<i>Morus tenuirostris</i>	Australian gannet	P	L	✓
<i>Pandion haliaetus</i>	Osprey	V	L, M	✓
<i>Phalacrocorax melanoleucos</i>	Little pied cormorant	P		✓
<i>Pterodroma neglecta neglecta</i>	Kermadec petrel	V	V	
<i>Puffinus griseus</i>	Sooty shearwater	P	L, M	
<i>Puffinus leucomelas</i>	Streaked shearwater	P	L, M	
<i>Puffinus pacificus</i>	Wedge-tailed shearwater	P	L, M	
<i>Puffinus tenuirostris</i>	Short-tailed shearwater	P	L, M	
<i>Sterna albifrons</i>	Little tern	E	L, M	✓
<i>Sterna bergii</i>	Crested tern	P	L	✓
<i>Sterna caspia</i>	Caspian tern	P	L, M	✓
<i>Sterna hirundo</i>	Common tern	P	L, M	✓
<i>Thalassarche bulleri</i>	Buller's albatross	P	V, M	
<i>Thalassarche cauta cauta</i>	Shy albatross	V	V, M	
<i>Thalassarche cauta salvini</i>	Savin's albatross	P	V, M	
<i>Thalassarche cauta steadi</i>	White-capped albatross	P	V, M	
<i>Thalassarche melanophris impavida</i>	Campbell albatross	P	V, M	
<i>Thalasseus bergii</i>	Crested tern	P	L	
<i>Todiramphus sanctus</i>	Sacred kingfisher	P	L	✓
Penguins				
<i>Eudyptes pachyrhynchus</i>	Fiordland penguin	P	L	✓
<i>Eudyptula minor</i>	Little penguin	P	L	✓
5. Plants				
<i>Chamaesyce psammogeton</i>	Sand spurge	E		NA
<i>Senecio spathulatus</i>	Coast groundsel	E		NA
7. Ecological Communities				
Coastal saltmarsh		E		NA
6. Endangered populations				
<i>Posidonia australis</i>	Brisbane Water	E		NA

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Table 2: Water quality data derived from *in situ* probe measurements. ANZECC (2000) Water Quality Guidelines for the protection of aquatic organisms shown ("-" = guideline not available). Data in red/shaded cells exceed ANZECC guideline.

Site	Depth	Replicate	Temperature	Salinity	pH	ORP	DO%	DOmg/L	Turbidity
ANZ			-	-	7.0-8.5	-	80-110	-	0.5-10
1	Surface	1	22.39	35.55	8.26	362	107.4	7.6	8.5
		2	22.40	35.54	8.24	362	106.4	7.5	8.4
	Bottom	1	22.36	35.59	8.22	361	104.7	7.4	8.3
		2	22.70	35.56	8.23	360	103.8	7.3	8.7
2	Surface	1	22.71	35.63	8.16	399	94.3	6.6	5.2
		2	22.70	35.80	8.17	397	94.3	6.6	7.7
	Bottom	1	22.68	35.83	8.17	394	90.8	6.4	9.3
		2	22.70	35.84	8.19	392	94.0	6.6	9.3
3	Surface	1	22.72	35.58	8.22	379	99.1	7.4	6.0
		2	22.73	35.68	8.19	379	99.0	6.9	5.9
	Bottom	1	22.67	35.73	8.12	332	99.1	6.9	5.6
		2	22.67	35.73	8.14	338	97.7	6.9	7.0
4	Surface	1	22.73	35.71	8.24	350	99.5	7.0	2.3
		2	22.74	35.70	8.23	351	99.8	7.0	4.0
	Bottom	1	22.58	35.75	8.21	353	95.4	6.7	6.7
		2	22.70	35.74	8.27	354	97.7	6.9	7.0
5	Surface	1	22.70	35.73	8.25	357	99.0	6.9	2.9
		2	22.71	35.73	8.24	357	98.8	6.9	4.4
	Bottom	1	22.59	35.75	8.21	358	93.5	6.6	8.9
		2	22.58	35.75	8.21	358	93.0	6.5	10.7
6	Surface	1	22.79	35.71	8.24	360	102.0	7.1	2.4
		2	22.80	35.70	8.23	360	102.7	7.1	4.4
	Bottom	1	22.80	35.73	8.24	358	103.3	7.2	10.1
		2	22.80	35.73	8.25	359	103.5	7.2	8.7
7	Surface	1	23.23	35.88	8.20	351	112.9	7.9	13.1
		2	23.14	35.88	8.22	353	114.4	7.9	13.7
	Bottom	1	23.16	35.84	8.27	353	118.9	8.2	13.6
		2	23.11	35.88	8.27	353	115.9	8.1	13.3

Table 3: Results of Permanova+ analyses comparing data obtained *in situ* by probe among sites ($n = 2$). **Bold font** indicates significant results. RED = Redundant term due to significant interaction term. See Appendix 4 for pairwise comparisons of sites and depths for significant main effects.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
<i>Temperature</i>						
Sites	6	1.0878	0.1813	35.83	0.0002	4989
Depths (Surface or Bottom)	1	0.0054	0.0054	1.07	0.3346	4930
Site x Depths	6	0.0420	0.0070	1.38	0.2948	4986
Residual	14	0.0709	0.0051			
Total	27	1.2061				
<i>Salinity</i>						
Sites	6	0.2122	0.0354	23.63	0.0002	4988
Depths	1	0.0142	0.0142	9.47	0.0094	4772
Site x Depths	6	0.0142	0.0024	1.58	0.2340	4993
Residual	14	0.0210	0.0015			
Total	27	0.2615				
<i>pH</i>						
Sites	6	0.0258	0.0043	17.94	RED	4644
Depths	1	0.0003	0.0003	1.21	RED	2840
Site x Depths	6	0.0111	0.0019	7.76	0.0012	4903
Residual	14	0.0034	0.0002			
Total	27	0.0405				
<i>ORP</i>						
Sites	6	5462.90	910.49	490.26	RED	4984
Depths	1	315.57	315.57	169.92	RED	4894
Site x Depths	6	1660.90	276.82	149.06	0.0002	4988
Residual	14	26.00	1.86			
Total	27	7465.40				
<i>DO mg/L</i>						
Sites	6	1321.20	220.20	195.92	RED	4988
Depths	1	11.96	11.96	10.64	RED	4933
Site x Depths	6	55.79	9.30	8.27	0.0008	4982
Residual	14	15.74	1.12			
Total	27	1404.70				
<i>%DO</i>						
Sites	6	5.869	0.978	74.02	RED	4880
Depths	1	0.080	0.080	6.08	RED	3640
Site x Depths	6	0.267	0.045	3.37	0.0326	4966
Residual	14	0.185	0.013			
Total	27	6.401				
<i>Turbidity</i>						
Sites	6	183.10	30.52	36.32	RED	4982
Depths	1	52.12	52.12	62.02	RED	4955
Site x Depths	6	43.22	7.20	8.57	0.0004	4991
Residual	14	11.76	0.84			
Total	27	290.19				

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Table 4: Water quality data derived from laboratory analyses. S1, S2, etc = Site 1, Site 2; R1, R2 = replicate samples; ANZECC (2000) Water Quality Guidelines for the protection of aquatic organisms shown ("- = guideline not available). Data in red/shaded cells exceed ANZECC guideline.

SAMPLE REFERENCE	Benzene µg/L	Toluene µg/L	BTEX			Total Petroleum Hydrocarbons			
			Ethyl Benzene µg/L	m, p - Xylene µg/L	o - Xylene µg/L	TPH C6 - C9 µg/L	TPH C10 - C14 µg/L	TPH C15 - C28 µg/L	TPH C29 - C36 µg/L
ANZECC:	-	-	-	-	-	-	-	-	-
S1R1	<1	<1	<1	<2	<1	<25	<25	<100	<100
S1R2	<1	<1	<1	<2	<1	<25	<25	<100	<100
S2R1	<1	<1	<1	<2	<1	<25	<25	<100	<100
S2R2	<1	<1	<1	<2	<1	<25	<25	<100	<100
S3R1	<1	<1	<1	<2	<1	<25	<25	<100	<100
S3R2	<1	<1	<1	<2	<1	<25	<25	<100	<100
S7R1	<1	<1	<1	<2	<1	<25	<25	<100	<100
S7R2	<1	<1	<1	<2	<1	<25	<25	<100	<100

SAMPLE REFERENCE	Trace Elements								Nutrients	
	Antimony µg/L	Arsenic µg/L	Cadmium µg/L	Chromium µg/L	Copper µg/L	Lead µg/L	Nickel µg/L	Zinc µg/L	TN mg/L	TP mg/L
ANZECC:	-	-	5.5	27.4/4.4	1.3	4.4	70	15	0.3	0.03
S1R1	<1	1.1	<0.1	<1	1.4	<1	<1	16	0.24	0.027
S1R2	<1	1.3	<0.1	<1	<1	<1	<1	2.5	0.28	0.045
S2R1	<1	1.4	<0.1	<1	<1	<1	<1	2.5	0.21	0.024
S2R2	<1	1.4	<0.1	<1	<1	<1	<1	<1	0.11	0.024
S3R1	<1	1.2	<0.1	<1	<1	<1	<1	18	0.15	0.023
S3R2	<1	1.3	<0.1	<1	<1	<1	<1	17	0.10	0.024
S7R1	<1	1.1	<0.1	<1	<1	<1	<1	4.5	0.18	0.026
S7R2	<1	1.3	<0.1	<1	<1	<1	<1	5.8	0.24	0.025

Table 5: Results of Permanova+ analyses comparing concentrations of selected water quality variables collected at the water surface among sites ($n = 2$). Excludes Site 6 (oyster farm area). **Bold font** indicates significant results.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	P(MC)
<i>Arsenic</i>							
Sites	3	0.0538	0.0179	1.5926	0.3754	10	0.3194
Residual	4	0.0450	0.0113				
Total	7	0.0988					
<i>Zinc</i>							
Sites	3	283.39	94.463	3.9997	0.1598	57	0.1100
Residual	4	94.47	23.618				
Total	7	377.86					
<i>Total Nitrogen</i>							
Sites	3	0.0208	0.0069	3.1394	0.1720	55	0.1590
Residual	4	0.0089	0.0022				
Total	7	0.0297					
<i>Total Phosphorous*</i>							
Sites	3	0.0002	0.0001	1.7055	0.0284	24	0.3048
Residual	4	0.0002	0.0000				
Total	7	0.0004					

* Note - all pairwise comparisons of sites statistically non-significant

Table 6: Sediment data. S1, S2, etc = Site 1, Site 2; R1, R2 = replicate samples; ANZECC (2000) Interim Sediment Quality Guidelines (ISQ) Low and High values shown ("- " = guideline not available). Data in red/shaded cells exceed ANZECC guideline.

SAMPLE REFERENCE	BTEX		Total Petroleum Hydrocarbons						
	Benzene mg/kg	Toluene mg/kg	Ethyl Benzene mg/kg	m, p - Xylene mg/kg	o - Xylene mg/kg	TPH C6 - C9 mg/kg	TPH C10 - C14 mg/kg	TPH C15 - C28 mg/kg	TPH C29 - C36 mg/kg
ANZECC ISQ-Low	-	-	-	-	-	-	-	-	-
ANZECC ISQ-High	-	-	-	-	-	-	-	-	-
S1R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S1R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S2R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S2R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S3R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S3R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S4R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S4R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S5R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S5R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S7R1	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100
S7R2	<0.5	<0.5	<0.5	<1	<0.5	<25	<50	<100	<100

SAMPLE REFERENCE	Trace Elements										Miscellaneous	
	Antimony mg/kg	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Lead mg/kg	Mercury mg/kg	Nickel mg/kg	Selenium mg/kg	Zinc mg/kg	Total %	Carbon - mg/kg
ANZECC ISQ-Low	2	20	1.5	80	65	50	0.15	21	-	200	-	-
ANZECC ISQ-High	25	70	10	370	270	220	1	52	-	410	-	-
S1R1	0.69	2.6	<0.1	9.4	9.5	12	0.03	7.5	<0.5	45	69.7	13400
S1R2	<0.5	2.3	<0.1	6.5	7.8	8.4	0.03	4.7	<0.5	39	69.4	11200
S2R1	<0.5	9.5	<0.1	12	6	11	0.10	5.1	<0.5	27	46.1	13700
S2R2	<0.5	6.5	<0.1	13	12	19	0.18	5	<0.5	47	56.9	14800
S3R1	<0.5	13	<0.1	34	27	47	0.19	14	1.3	130	28.9	38100
S3R2	<0.5	12	<0.1	36	30	47	0.16	14	1.2	140	29.8	33600
S4R1	<0.5	12	<0.1	34	28	45	0.17	13	1.1	130	29.9	36800
S4R2	<0.5	15	<0.1	32	19	41	0.19	13	0.8	100	35.8	30700
S5R1	<0.5	11	<0.1	29	24	39	0.17	12	0.69	110	36.2	30400
S5R2	<0.5	13	<0.1	31	25	39	0.19	12	1.6	120	22.4	34800
S7R1	<0.5	3.3	<0.1	11	11	10	0.09	9.1	<0.5	47	71.5	10800
S7R2	0.6	3.8	<0.1	18	25	14	0.10	20	<0.5	97	63.2	22200

Table 7: Results of Permanova+ analyses comparing concentrations among sites of selected sediment quality variables collected at the seabed ($n = 2$). Excludes Site 6 (oyster farm area). **Bold font** indicates significant results. See Appendix 8 for pairwise comparisons of sites for significant main effects.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
<i>Arsenic</i>						
Sites	5	228.88	45.78	23.535	0.0018	2031
Residual	6	11.67	1.95			
Total	11	240.55				
<i>Chromium</i>						
Sites	5	1395.50	279.10	47.567	0.0034	2529
Residual	6	35.21	5.87			
Total	11	1430.70				
<i>Copper</i>						
Sites	5	696.60	139.32	5.1301	0.0528	2428
Residual	6	162.95	27.16			
Total	11	859.55				
<i>Mercury</i>						
Sites	5	0.04	0.01	10.702	0.0150	267
Residual	6	0.00	0.00			
Total	11	0.04				
<i>Nickel</i>						
Sites	5	171.47	34.29	3.249	0.0784	1401
Residual	6	63.33	10.56			
Total	11	234.80				
<i>Lead</i>						
Sites	5	2896.60	579.32	63.802	0.0028	1945
Residual	6	54.48	9.08			
Total	11	2951.10				
<i>Zinc</i>						
Sites	5	17232.00	3446.40	10.247	0.0090	1959
Residual	6	2018.00	336.33			
Total	11	19250.00				
<i>Total Organic Carbon (TOC)</i>						
Sites	5	1.19E+09	2.39E+08	13.473	0.0152	3878
Residual	6	1.06E+08	1.77E+07			
Total	11	1.30E+09				

9 Figures

Figure 1: Habitat map of species of marine vegetation present in the vicinity of the current jetty and proposed marina structures, Koolewong Marina, Brisbane Water Drive, Gosford.

Figure 2: Positions of samples taken for water quality and sediment chemistry

Figure 3: Mean water temperature and salinity pooled over depth measured in situ using a water quality probe.

Figure 4: Mean values of water quality indicators measured *in situ* using a water quality probe.

Figure 5: Percentage composition of sediment made up of fine fraction (light grey), sand fraction (dark grey) and coarse fraction (black) from sites around proposed development.

Figure 6: Mean concentration of sediment variables sampled at 5 sites in the vicinity of the proposed marina development.

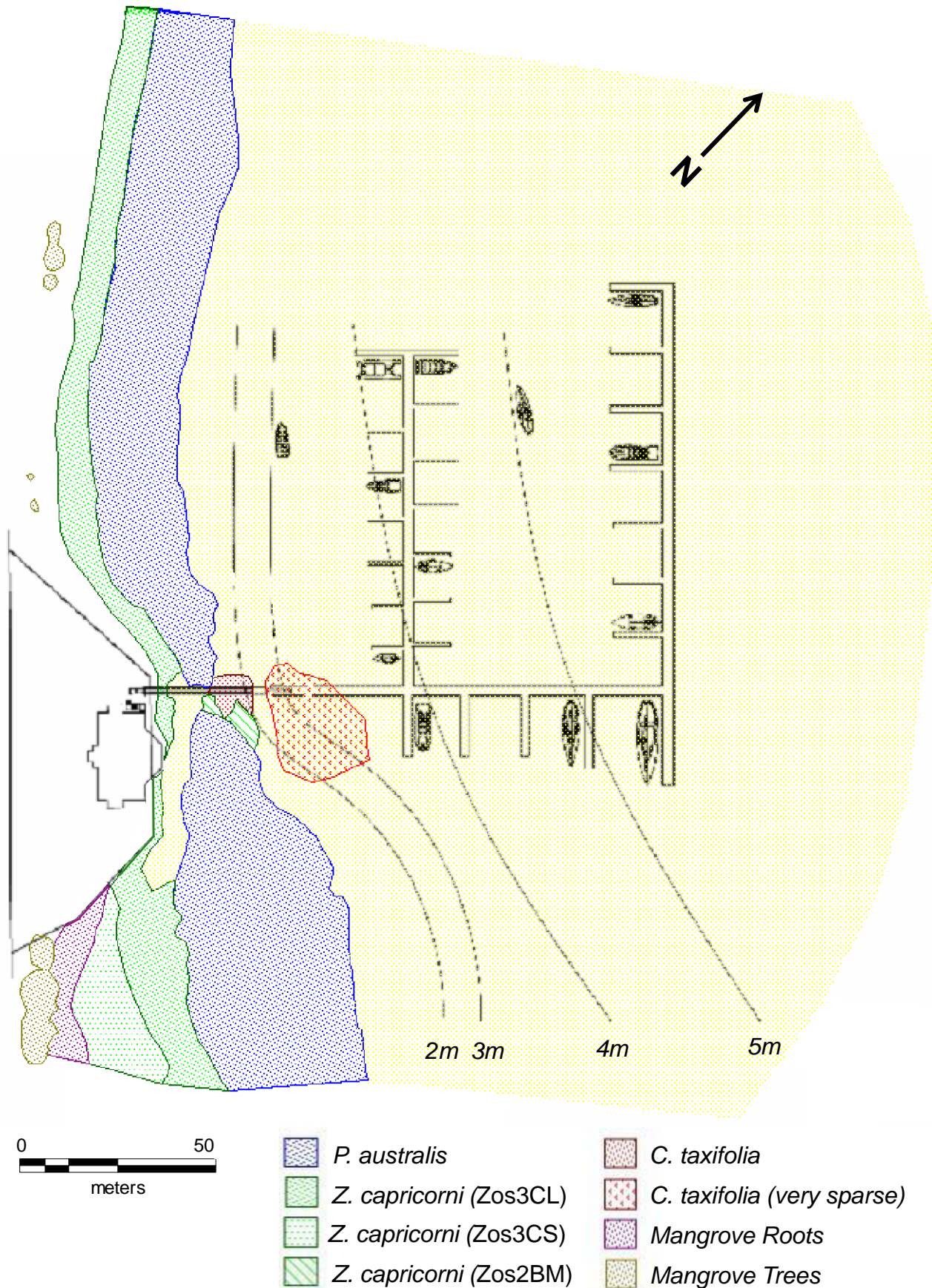


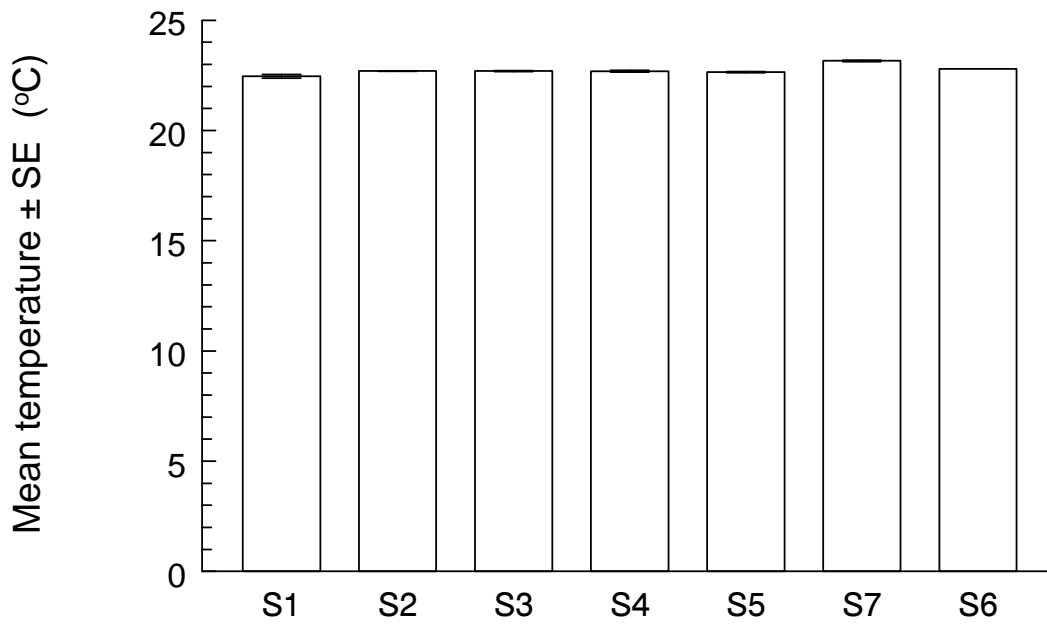
Figure 1: Habitat map of marine vegetation present in the vicinity of the current jetty and proposed marina structures (ADW Johnson 2010), Koolewong Marina, Brisbane Water Drive, Gosford. Date of most recent inspection - 7 March 2011.



Figure 2: Positions of sample sites taken for water quality and sediment chemistry. Two replicate samples taken at each site.

Image source: Google Earth

a. Water Temperature (°C)



b. Salinity (ppt)

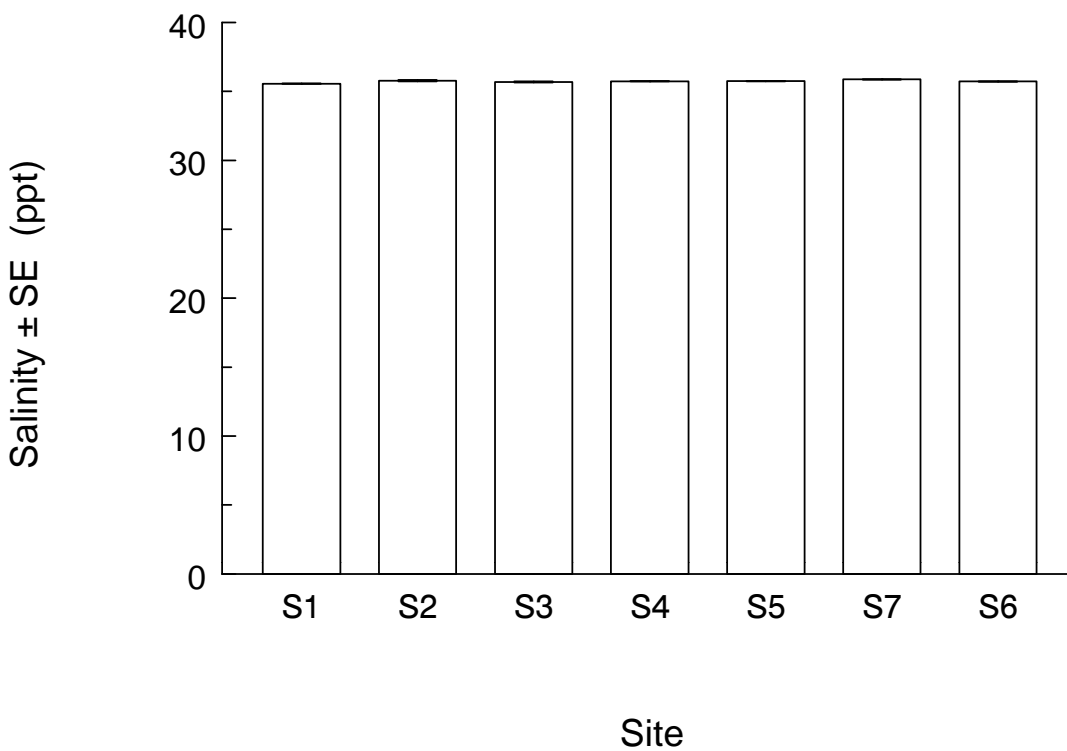


Figure 3: Mean water temperature (a) and salinity (b) pooled over depth (± 1 SE, $n = 4$) measured in situ using a water quality probe.

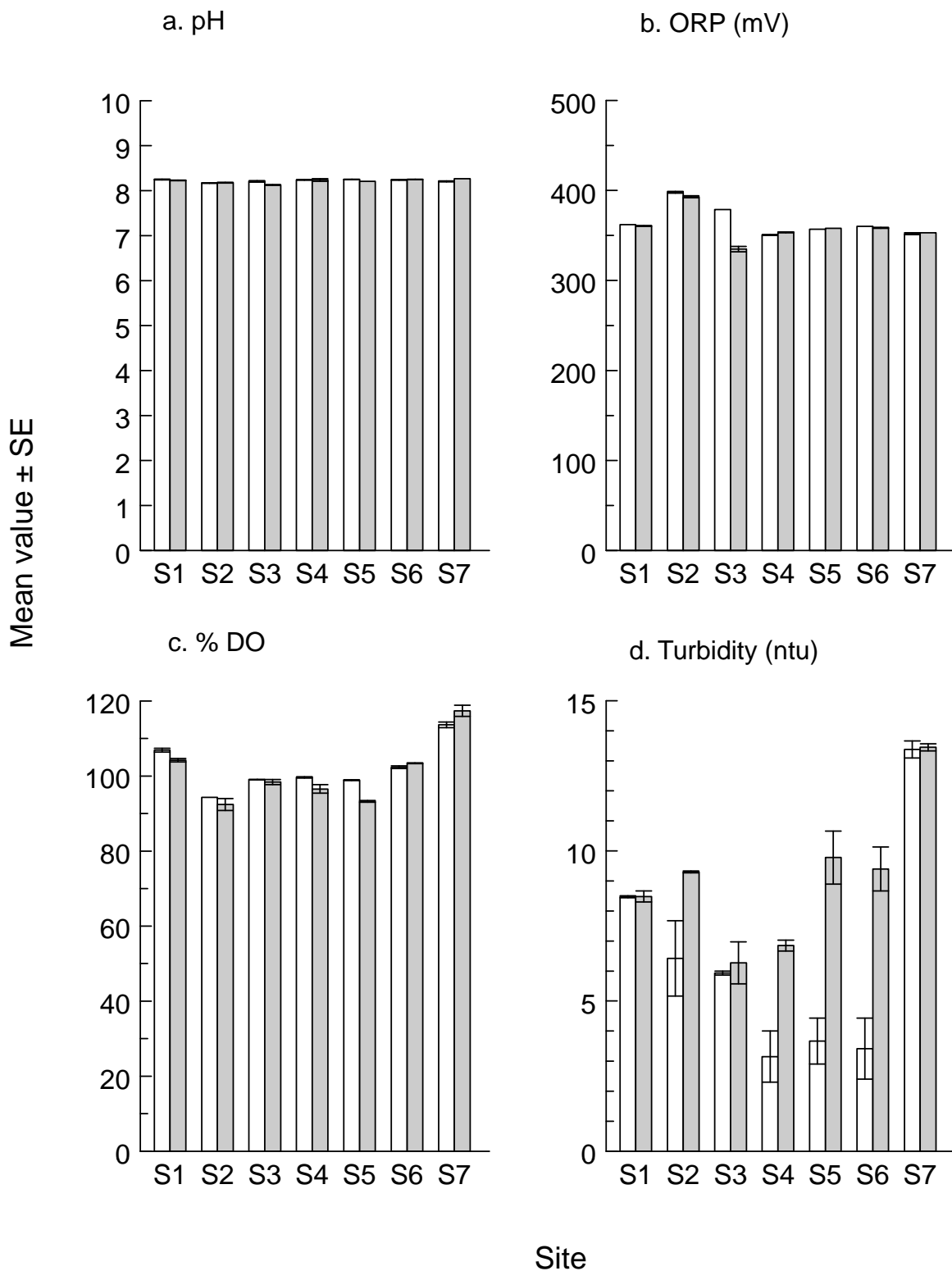


Figure 4: Mean values (± 1 SE, $n = 2$) of water quality indicators measured *in situ* using a water quality probe. Open bars = surface samples; grey bars = bottom samples.

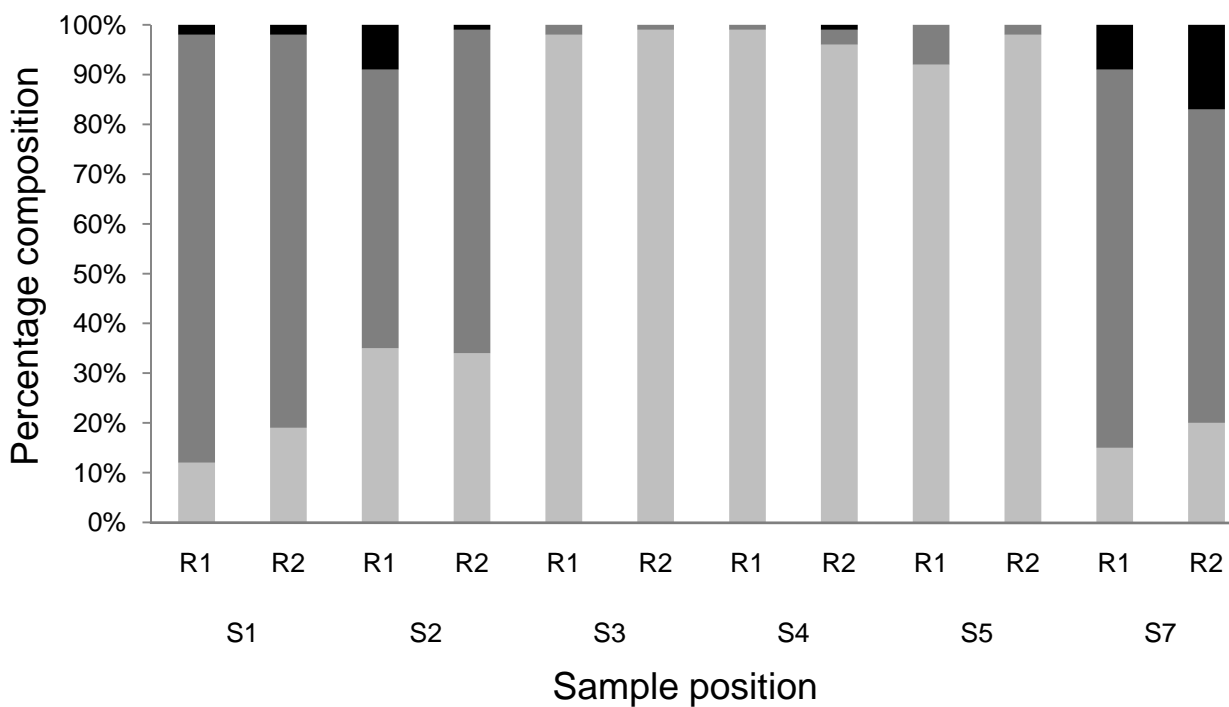


Figure 5: Percentage composition of sediment made up of fine fraction (light grey), sand fraction (dark grey) and coarse fraction (black) from sites around proposed development. Site 6 (oyster farm) not sampled. Position of sites shown on Figure 2. R = Replicate sample

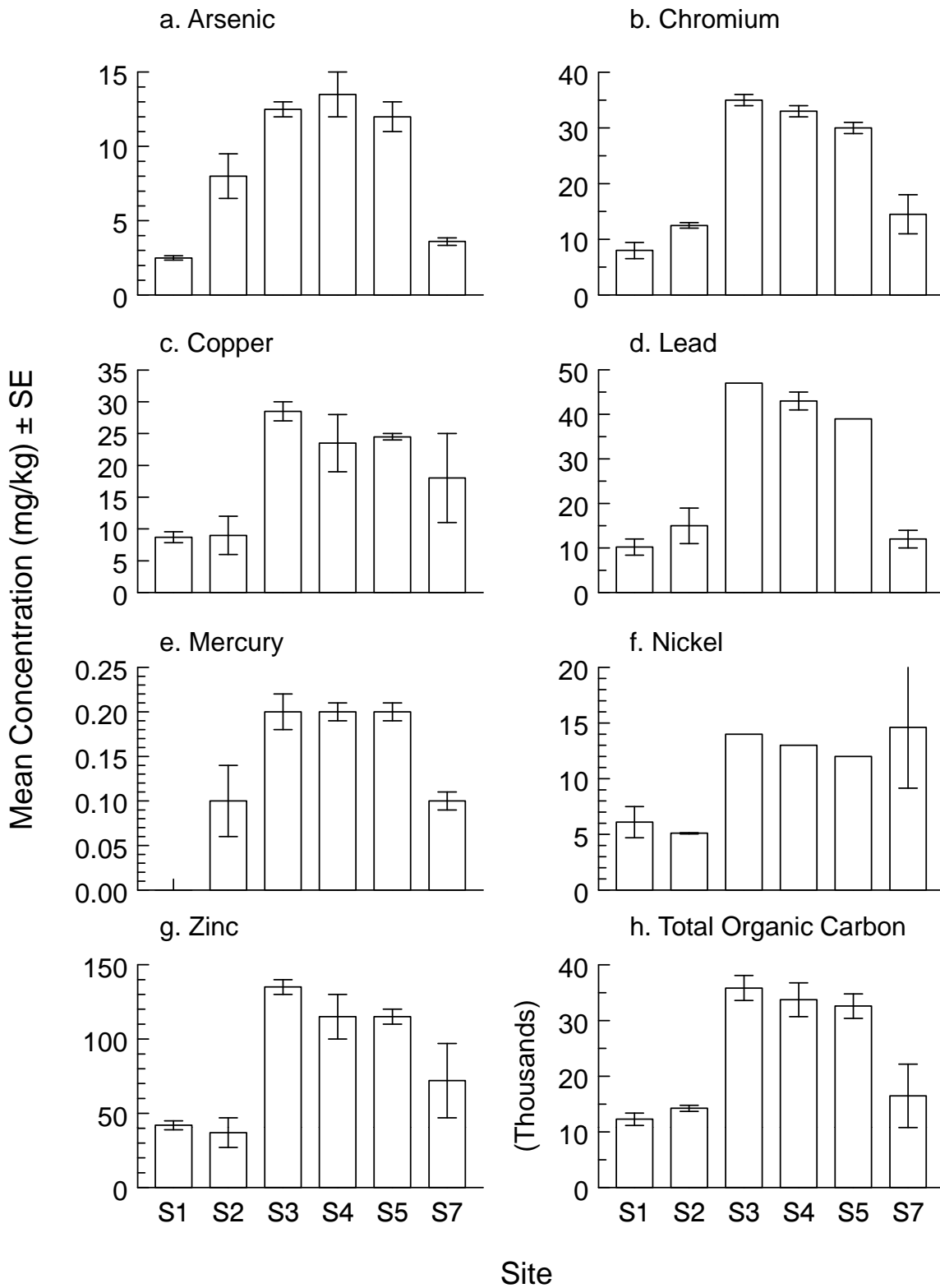


Figure 6: Mean concentration (\pm SE, $n = 2$) of sediment variables sampled at 5 sites in the vicinity of the proposed marina development.

10 Plates

Plate 1: Foreshore view of the 'The Boathouse' restaurant at the proposed Koolewong Marina site and seaward view of the existing jetty and berthing piles from the shore.

Plate 2: North-western stormwater drain seen at a low tide and high tide.

Plate 3: Sydney rock oysters (*Sacostrea glomerata*) growing on the rock wall surrounding the restaurant complex and the limpets *Patelloida mimula* and *Cellana tramoserica* and gold-mouthed coniwinks (*Bembicium auratum*).

Plate 4: Siphon limpets *Siphonaria denticulata*, Sydney rock oysters and gold-mouthed coniwinks on the rock wall and Sydney rock oysters growing on the restaurant support pylons.

Plate 5: View of southern shoreline at low tide showing the common white faced heron (*Egretta novaehollandiae*) observed wading through seagrass.

Plate 6: The pest algae *Caulerpa taxifolia* observed near the existing jetty.

Plate 7: Dense, long leaved *Posidonia australis* and dense, long leaved *Zostera capricorni* observed in the survey area.

Plate 8: *Z. capricorni* adjacent to *P. australis* and *Z. capricorni* adjacent to seagrass wrack near the low tide mark.

Plate 9: North-western shoreline at low tide with partially exposed seagrass in foreground and scattered grey mangroves in background and at high tide.

Plate 10: View of south-eastern shoreline at low tide with exposed seagrass and grey mangroves and associated pneumatophores and at high tide.



Plate 1: Upper: Foreshore view of the 'The Boathouse' restaurant at the proposed Koolewong Marina site (taken from existing jetty). **Lower:** Seaward view of the existing jetty and berthing piles from the shore.



Plate 2: Upper: North-western stormwater drain seen at a low tide. **Lower:** High tide.



Plate 3: Upper: Sydney rock oysters (*Sacostrea glomerata*) growing on the rock wall surrounding the restaurant complex. The limpet *Patelloida mimula* (Red arrows) can be seen living on the oysters. **Lower:** A limpet *Cellana tramoserica* (centre) and gold-mouthed conniwinks (*Bembicium auratum*).



Plate 4: Upper: Siphon limpets *Siphonaria denticulata* (Red arrows), Sydney rock oysters and gold-mouthed conniwinks. **Lower:** Sydney rock oysters growing on the restaurant support pylons.



Plate 5: Upper: View of southern shoreline at low tide showing the common white faced heron (*Egretta novaehollandiae*) observed wading through seagrass. **Lower:** Close-up common white faced heron (*Egretta novaehollandiae*) observed wading through seagrass at low tide .

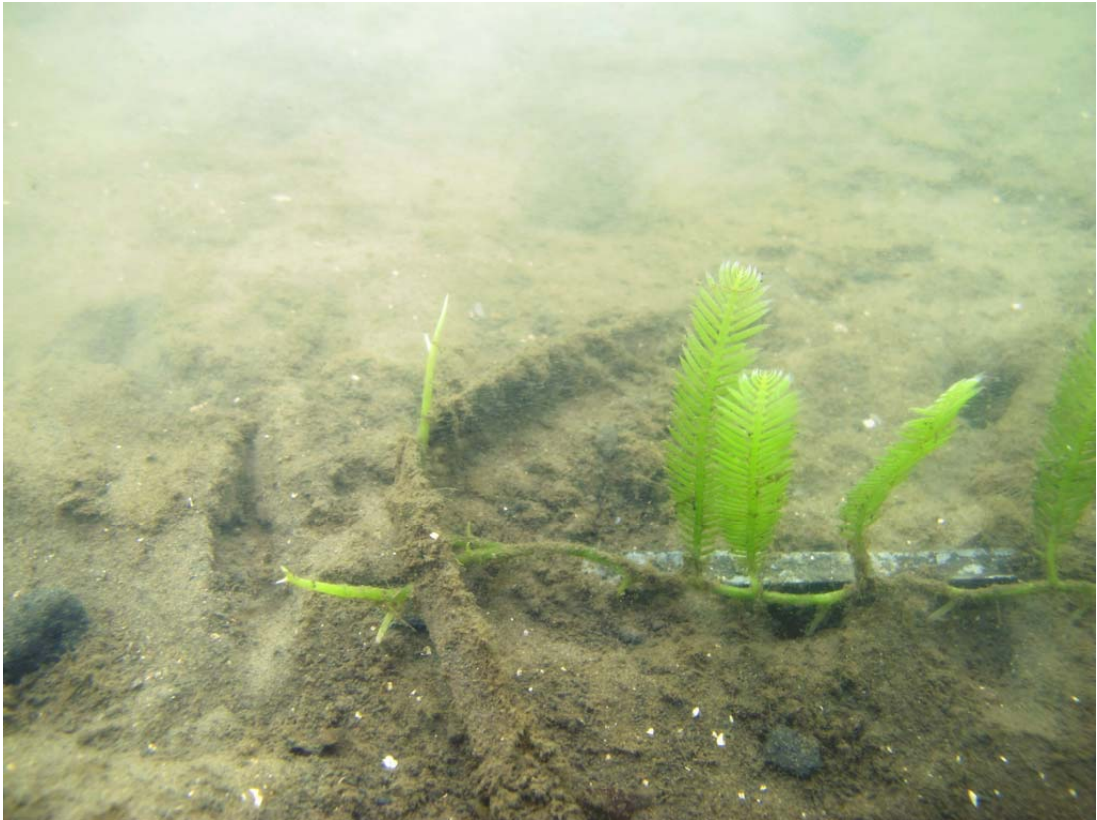


Plate 6: Upper: The pest algae *Caulerpa taxifolia* observed in high density south-east of the existing jetty **Lower:** A shoot of *C. taxifolia* spreading into nearby unvegetated sediment to the north-west of the existing jetty.

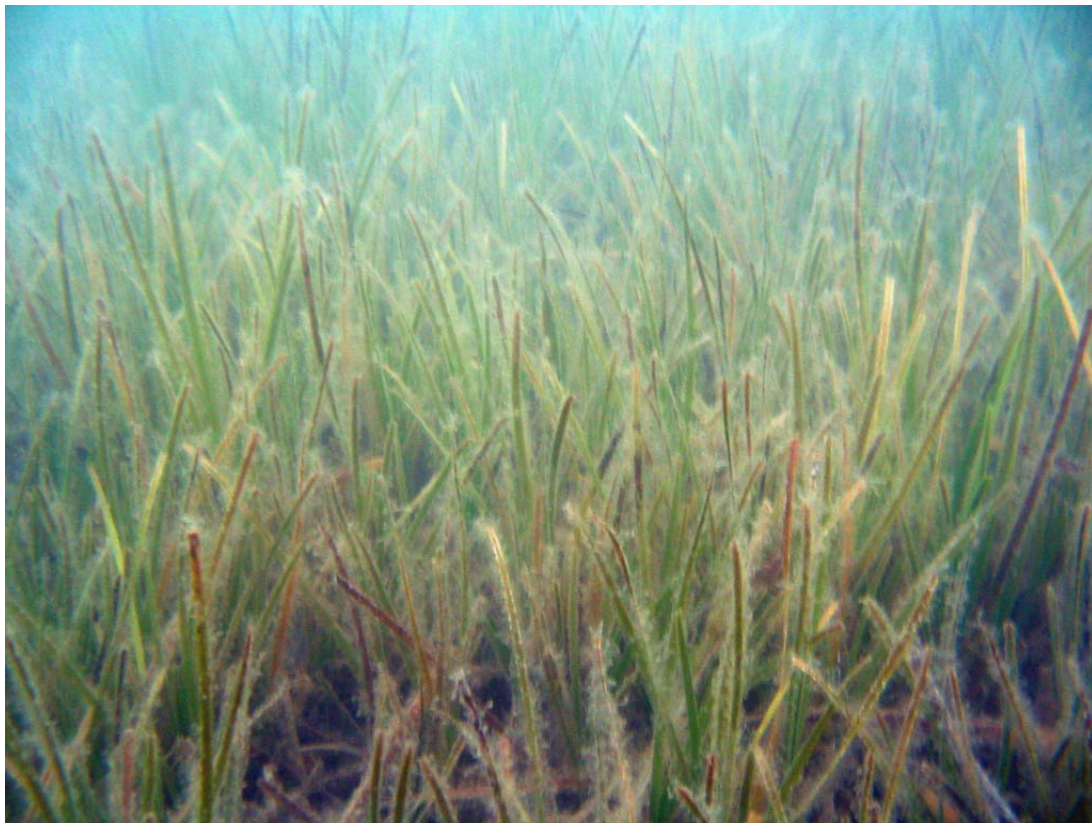
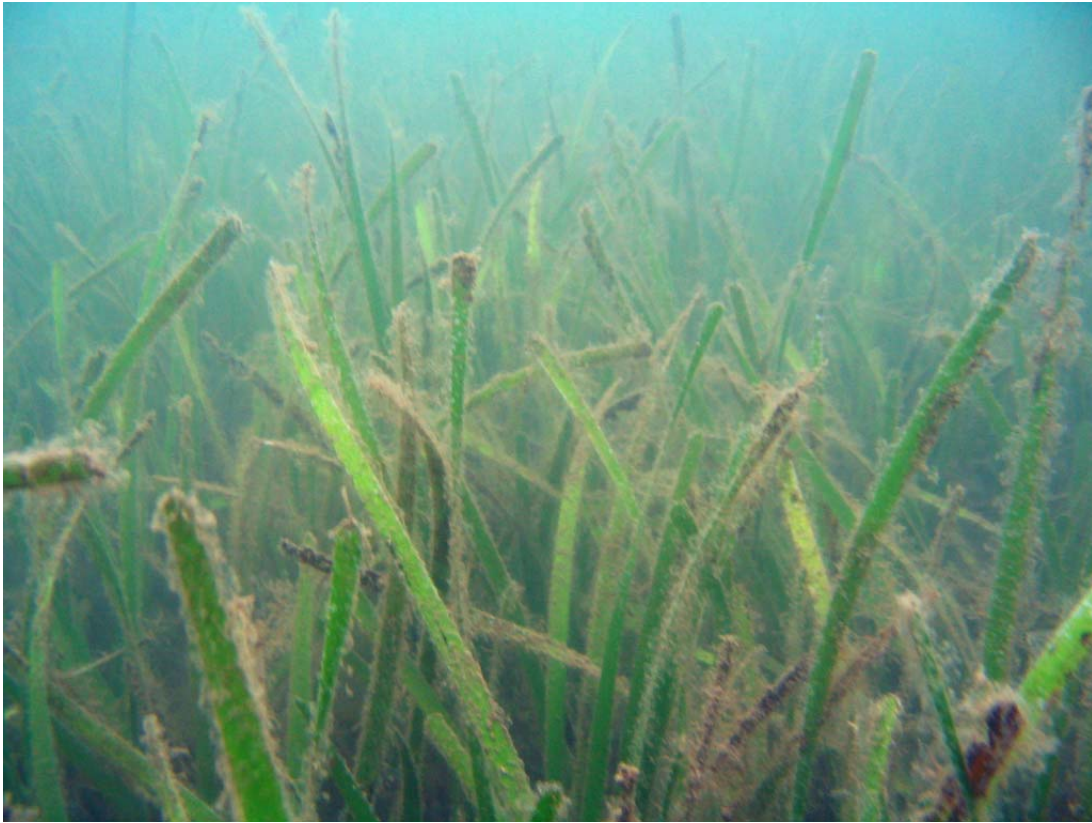


Plate 7: Upper: Dense, long leaved *Posidonia australis* seagrass observed in the survey area.
Lower: Dense, long leaved *Zostera capricorni* seagrass also observed in the survey area.

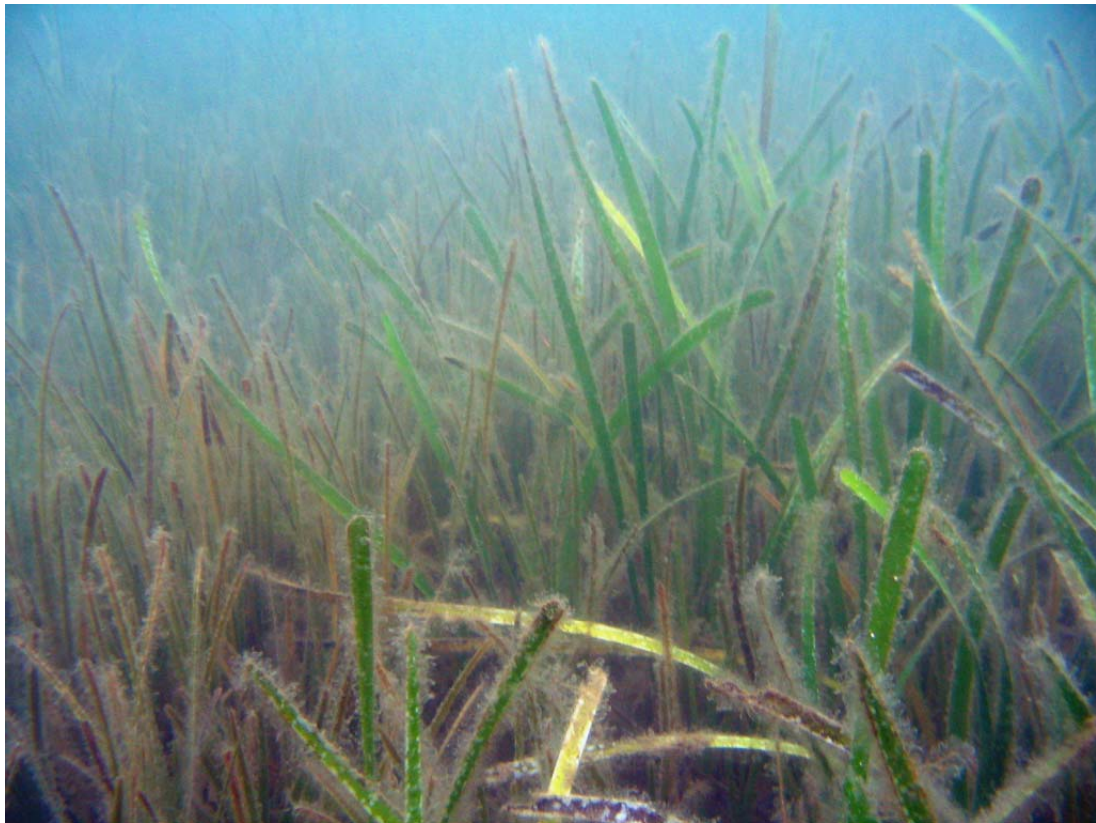


Plate 8: Upper: Adjacent beds of *Z. capricorni* (left) and *P. australis* (right). **Lower:** *Z. capricorni* and seagrass wrack near the low tide mark.



Plate 9: Upper: North-western shoreline at low tide with partially exposed seagrass in foreground and scattered grey mangroves in background. **Lower:** North-western shoreline at high tide.



Plate 10: Upper: View of south-eastern shoreline at low tide with exposed seagrass and grey mangroves and associated pneumatophores. Stormwater drain in foreground. **Lower:** View of south-eastern shoreline at high tide.

11 Appendices

Appendix 1. ‘Assessment of Significance’ for threatened species, populations and communities listed under the *Threatened Species Conservation Act 1995* (TSC Act) or *Fisheries Management Act 1994* (FM Act)

Appendix 2. ‘Assessment of Significance’ for Threatened Species, Populations and Communities Protected Under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Appendix 3: Geographical positions of sites where water and sediment were sampled.

Appendix 4: Results of pair-wise Permanova+ tests for significant factors for probe data, sampled on 7/3/2011.

Appendix 5: Report from external testing laboratory on chemical composition of water samples collected in the vicinity of the proposed development, 7/3/2011.

Appendix 6: Report from external testing laboratory on grain size composition of sediments collected in the vicinity of the proposed development, 7/3/2011.

Appendix 7: Report from external testing laboratory on chemical composition of sediments collected in the vicinity of the proposed development, 7/3/2011.

Appendix 8: Results of pair-wise Permanova+ tests comparing sites for significant factors for sediment chemistry data, with samples collected on 7/3/2011.

Appendix 1. ‘Assessment of Significance’ for threatened species, populations and communities listed under the *Threatened Species Conservation Act 1995* (TSC Act) or *Fisheries Management Act 1994* (FM Act)

MARINE REPTILES

There are two listed marine turtles under the TSC Act and for the purposes of this assessment they have been grouped because they have similar distribution in NSW and many similar ecological requirements.

Species Group: Marine Turtles
<p>Species and Status:</p> <ul style="list-style-type: none"> ■ Loggerhead turtle (<i>Caretta caretta</i>) - endangered ■ Green turtle (<i>Chelonia mydas</i>) – vulnerable
<p>a) <i>In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.</i></p> <p>Most of the threatened marine turtles that potentially would be affected in some way by the proposal tend to prefer warmer waters, ranging from tropical to warm temperate seas (Marquez 1990). The green turtle is generally found in the more northern latitudes of Australia although resident groups of green turtles have been found in NSW, with some as far south as Jervis Bay. There have been reports of green turtles in Lake Macquarie and also in Brisbane Water. Resident populations also appear to have established particularly near warm water outfalls such as in Lake Macquarie where a study is underway to assess the populations. Green turtles feed on seaweeds and seagrasses although juveniles may be carnivorous (Environment Australia 2003).</p> <p>Loggerhead turtles occur in coral reefs, bays and estuaries in tropical and warm temperate waters off the coast of QLD, Northern Territory (NT), Western Australia (WA) and NSW. Like green turtles, there are also resident groups of loggerhead turtles in the waters of northern NSW. Loggerheads are carnivorous.</p> <p>Although these species occur within NSW estuaries, Brisbane Water is outside the range of known nesting and mating areas for the two turtle species. The nesting and mating grounds for the listed turtle species generally occur in more northern latitudes.</p> <p>By-catch of marine turtles in fisheries, entanglement and ingestion of marine debris, coastal</p>

development, loss of habitat and deterioration of water quality are significant threats to marine turtles. All the marine turtles scheduled under the legislation are vulnerable to hunting through much of their range, particularly in developing countries, although the hunting of turtles within NSW waters is prohibited. Although no populations are listed as endangered, the loss of only a few individuals could still affect the viability of local populations. Potential impacts to marine turtles as a result of the proposed marina at Koolewong include deterioration of water quality and the increased risk of boat strike. Marine turtles are vulnerable to boat strike when at the surface to breathe and rest between dives. This is considered a particular issue in waters adjacent to large urban populations (Limpus and Reimer 1994). Loggerhead turtles of the eastern Australian population have been identified as affected by boat strike, although this appears to be more of an issue in Queensland waters where areas of high incidence of boat strike have been identified.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or

ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.

Not applicable.

d) In relation to the habitat of a threatened species, population or ecological community:

i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and

ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and

iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

Estuarine habitats, including seagrass beds provide foraging habitat for marine turtles. Beds of strapweed (*Posidonia australis*) and also eelgrass (*Zostera capricorni*) occur adjacent to

where the marina is proposed, however, there would be no direct loss or disturbance to seagrass beds during the construction or operation of the marina at Koolewong. There is a low risk that seagrass beds may be affected by reduced light attenuation as a result of increased turbidity caused during pile driving works, although this would be unlikely to have any measurable impact as the works would be short-term and localised. It is very unlikely that this could occur to the extent that any area of marine turtle habitat would become isolated or removed such that this could affect the long-term survival of a turtle population.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

Not applicable.

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

There is an approved Commonwealth Recovery Plan for Marine Turtles in Australia (Environment Australia 2003). The specific objectives of the recovery plan are as follows.

- To reduce the mortality of marine turtles and, where appropriate, increase natural survivorship, including through developing management strategies with Aboriginal and Torres Strait Islander communities for the sustainable use of marine turtles;
- To develop programs and protocols to monitor marine turtle populations in Australia, assess the size and status of those populations, the causes of their mortality and address information gaps;
- To manage factors that affect marine turtle nesting;
- To identify and protect habitats that are critical for the survival of marine turtles;
- To communicate the results of recovery actions and involve and educate stakeholders; and
- To support and maintain existing agreements and develop new collaborative programs with neighbouring countries for the conservation of shared turtle populations.

In NSW, DECCW has prepared Priority Action Statements to promote the recovery of threatened species within NSW they include a total of 40 priority actions for marine turtle species, a high priority action within each species of marine turtles priority action plan is to 'liaise with the Australian and other State governments over the implementation of the national marine turtle recovery plan'. Objective A of the Commonwealth recovery plan for marine turtles aims to 'reduce the mortality of marine turtles'. There would potentially be negative effects on marine turtles within the vicinity of the marina if there were increased risk of boat strike. Given the relative small scale of the marina (approximately 50 berths) and the

existing level of boating activity, it is unlikely that the increased risk of boat strike would be of a magnitude to substantially increase mortality of marine turtles within Brisbane Water, although this could add to the cumulative impact. The proposal is otherwise consistent with the objectives of the Commonwealth recovery plan for marine turtles.

g) Whether the action proposed constitutes or is part of a key threatening process (KTP) or is likely to result in the operation of, or increase the impact of, a KTP.

The only KTP listed under State and Commonwealth legislation relevant to the current proposal would be 'the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW'. (FM Act). Boats can act as vectors for marine pests and algae which can be transported via anchor chains and fishing gear. The noxious algae *Caulerpa taxifolia* is of particular concern as it has been observed within the study area, is easily spread, can grow rapidly and may potentially out-compete native seagrasses.

Conclusion:

It is likely that green and loggerhead turtles may occur within Brisbane Water on occasion. There is potential for a cumulative increase in boating activity and risk of boat strike, however, this is not considered to be a current issue within Brisbane Water and would be mitigated through existing zoning of appropriate boat speeds within the estuary. Given the existing level of boating activity within Brisbane Water, the addition of the marina at Koolewong would be very unlikely to exacerbate the overall risk level. A management plan should be developed to control the impacts of construction works on surrounding seagrass habitat and turbidity levels. This may involve the use of silt curtains around pile driving works and marking of seagrass beds to ensure they are not disturbed during construction works and future operational activity.

No species impact statement is recommended for any of the marine turtles.

SHOREBIRDS

There are 11 listed shorebirds under the TSC Act and for the purposes of this assessment they have been grouped because they have similar distribution in NSW and many similar ecological requirements.

Species Group: Shorebirds

Species and Status:

- Pied oyster catcher (*Haematopus longirostris*) - endangered
- Great knot (*Calidris tenuirostris*) - vulnerable
- Greater sand plover (*Charadrius leschenaultia*) - vulnerable
- Lesser sand plover (*Charadrius mongolus*) - vulnerable
- Sooty oyster catcher (*Haematopus fuliginosus*) - vulnerable
- Black bittern (*Ixobrychus flavicollis*) - vulnerable
- Broad-billed sandpiper (*Limicola falcinellus*) - vulnerable
- Black tailed godwit (*Limosa limosa*) - vulnerable
- Terek sandpiper (*Xenus cinereus*) - vulnerable
- Painted snipe (*Rostratula australis*) - endangered
- Little tern (*Sterna albifrons*) - endangered
- Osprey (*Pandion halieatus*) – vulnerable

a) *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*

The majority of birds listed are shore birds or 'waders' (i.e. those birds commonly found on coastal shores, including beaches, rocky shores, mudflats, tidal wetlands and lagoons). These include plovers and sandpipers in the families Charadriidae and Scolopacidae, snipes and oystercatchers among others (Australian Museum 2010). The exception to this is the little tern (*Sterna albifrons*) and osprey (*Pandion halieatus*).

Wading birds feed on marine invertebrates (including molluscs, worms and crustaceans), small fish that live within intertidal sand and mudflats. Small reptiles, earthworms, seeds and vegetation may also form part of their diet. Waders feed in the shallows or over exposed mud by probing their long slender bills into the substratum. Bill length, legs, body-structure, size and foraging techniques may vary subtly or markedly differ between groups of waders (Pizzey and Knight 1997). Important nesting areas may include sandbanks, sandpits, islands in estuaries, mangroves and riparian vegetation adjacent to the waterway. Nesting

often takes place close to the ground which can make these birds vulnerable to disturbance.

Terns dive into the water to catch fish or other food. They may enter the water from flight, or dive from the surface of the water. Ospreys fish over clear, open water hovering before plunging into the water to catch their prey. Nests are made high up in dead trees or in dead crowns of live trees, usually within one kilometre of the sea. (NSW DECCW 2010h).

Ospreys favour coastal areas, particularly the mouths of estuaries, lagoons and lakes.

The proposed marina will not impinge upon intertidal flats which is an important feeding habitat for wading birds. Given the relatively small area of waterway, it would be highly unlikely to affect the feeding behaviour of either the little tern or osprey.

It is possible that noise and vibration caused during construction works (particularly pile driving) may cause short-term disturbance to birds roosting nearby. Contamination of benthic sediments within the footprint of the proposed marina may be an issue if existing sediments are disturbed during pile driving and/or from the corrosion of anti-fouling agents used on boat hulls and jetty piles. Contaminants may be ingested by benthic invertebrates and assimilated up the food chain to shorebirds, diving birds and raptors which feed upon benthic animals or small fish. However, analysis of existing sediments indicate that disturbance of the existing sediments would not pose a contamination risk. All vessels berthed at the proposed marina would be less than 25 m length and hence are not permitted to use tin based anti-fouling paints. Copper based paints are less damaging to the marine environment and do not readily bioaccumulate (Clark 1997). Given the relatively small-scale of the proposed marina the contamination impacts are likely to be negligible and impacts on wading birds are unlikely to be an issue.

Hence, it is unlikely that the proposal would cause adverse impacts that would result in a viable local population of wading birds being placed at risk of extinction.

b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.

Not applicable.

c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or

ii) is likely to substantially and adversely modify the composition of the ecological

community such that its local occurrence is likely to be placed at risk of extinction.

Not applicable.

d) In relation to the habitat of a threatened species, population or ecological community:

i) the extent to which habitat is likely to be removed or modified as a result of the action proposed; and

ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and

iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.

Feeding habitat important to wading birds may include tidal sand and mud flats. Important nesting areas may include sandbanks, sandpits, islands in estuaries, mangroves and riparian vegetation adjacent to the waterway. No areas of intertidal flat that might be important feeding habitat for shorebirds would be removed, fragmented or isolated to the extent that it could affect the long-term survival of a species of wading bird.

e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).

Not Applicable.

f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.

Priority actions have been identified to help protect and/or recover several of the threatened wading birds. The priority actions relevant to the proposal are listed below:

- Avoid disturbance of nesting sites from lake and estuary openings during breeding season (Medium priority) – pied oyster catcher;
- Minimise human disturbance at identified key foraging sites (disturbance from 4WDs, recreational users, dog-walkers, fishermen etc.) (Medium priority) – great knot, greater sand plover, lesser sand plover, black tailed godwit, terek sandpiper;
- Assess threats at key breeding sites (Medium priority) – sooty oyster catcher.

As the proposed marina will not impinge upon key nesting or foraging sites and there is already a moderate level of disturbance from the adjacent main road the action proposed is considered to be consistent with the actions of the recovery or threat abatement plans.

g) Whether the action proposed constitutes or is part of a key threatening process (KTP) or is likely to result in the operation of, or increase the impact of a KTP.

The only KTP listed under State and Commonwealth legislation relevant to the current proposal would be 'the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW'. (FM Act). Boats can act as vectors for marine pests and algae which can be transported via anchor chains and fishing gear. The noxious algae *Caulerpa taxifolia* is of particular concern as it has been observed within the study area, is easily spread, can grow rapidly and may potentially outcompete native seagrasses.

Conclusion:

Construction and operation of the marina is unlikely to cause any significant impacts to wading birds within the study area as no habitat important for nesting or feeding would be lost as a result of the development. Disturbance from noise or vibration during construction would be temporary and localised and at worst would result in birds moving to similar roosting areas nearby. Furthermore, the area within the vicinity of the proposed marina is relatively sparse in terms of vegetation suitable for roosting habitat.

No species impact statement is recommended for any of the wading birds.

ESTUARINE VEGETATION

Species Name: Strapweed (*Posidonia australis*)

Status: Endangered Population - Schedule 4, FM Act

a) *In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.*

Not applicable.

b) *In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.*

Posidonia australis meadows at Port Hacking, Botany Bay, Port Jackson, Pittwater, Brisbane Water and Lake Macquarie are listed as endangered populations under Part 2 Schedule 4 of the FM Act.

Posidonia beds are distributed throughout Brisbane Water, with the exception of the openings to Erina Creek and Narara Creek. No seagrass occurs over the footprint of where the proposed marina would be located, although extensive fringing beds do occur directly to the west of the proposed development.

Posidonia australis beds are composed of a rhizome mat buried under the sediment with vertical shoots emerging through the sediment. Each shoot carries 2 – 4 strap-like leaves up to 60 cm long and 1 – 2 cm wide and can be found just below the water surface to depths of up to 15 m depending on light attenuation, but are more commonly restricted to shallower depths in disturbed bays (Edgar 1997, Watford and Williams 1998).

Sexual reproduction in *Posidonia australis* is by the production of monoecious flowers that are pollinated underwater. Fruits are produced that float and can be distributed by currents. However, seedlings are rarely observed (except in some coastal lakes) and it has been estimated that seedlings can take decades to develop into mature plants (Kirkman 1998, Meehan and West 2004). The development of mature meadows from seedlings has not been observed for any *Posidonia* species (FSC 2010). As a result, *Posidonia australis* bed establishment and regrowth occurs primarily through the slow process of horizontal rhizomatous growth (West 1983, Meehan & West 2000) and this is the most critical life cycle component for the persistence and recovery of *Posidonia australis* populations. The slow development of individual plants, the likely low level of dispersal of fruit and seeds and the slow expansion rate of meadows mean that existing areas of *Posidonia australis* within these

estuaries and embayments can effectively be considered as isolated populations in respect to their long-term survival (FSC 2010).

Threats to the persistence of *Posidonia australis* meadows relevant to the proposal include:

- Physical damage (from boat propellers, anchors and moorings);
- Spread of the invasive pest alga *Caulerpa taxifolia*;
- Reduction in water quality.

A relatively small localised increase in boating activity would not represent a substantial risk to *Posidonia* beds. Provision of dedicated berthing facilities may reduce the need for anchoring and hence damage to *Posidonia* beds in the area. All seagrasses, including *Posidonia australis*, are protected within NSW and cannot be harmed or removed and there are boating guidelines and regulations enforced by NSW Maritime and I&I NSW to address this issue. *Caulerpa taxifolia* is present within Brisbane Water and has been found within the study area, including where the marina is proposed. *Caulerpa* can grow rapidly, leading to concerns it could out-compete native seagrass. Small fragments of *Caulerpa* can grow into new plants and create large colonies. Research results to date from NSW indicate that dense native seagrass beds are relatively resistant to invasion from *Caulerpa*, however, sparse seagrass beds (*Zostera* sp.in particular) may be at risk (I&I NSW 2010)

As part of the management plan during construction of the marina, the area of *Caulerpa* should be identified and construction teams notified and care taken to avoid its spread. Boat users at the marina should be made aware of existing guidelines to avoid the further spread of *Caulerpa*.

There is a low risk that seagrass beds may be affected by reduced light attenuation as a result of increased turbidity caused during pile driving works, although this would be unlikely to have any measurable impact as the works would be short-term and localised.

Measurement of turbidity and/or suspended sediments during pile driving could be used to provide a trigger to management action, such as postponement of pile driving until water conditions improve. If concentrations remain unacceptably high, the use of silt curtains around pile driving works may be necessary and would help minimise any the potential impact on adjacent *Posidonia* beds. These matters could be incorporated into a plan of management to assist with construction activities.

It is not expected that the development of the marina at Koolewong and the associated boating activity could lead to the extinction of or substantially impact upon the *Posidonia* population within Brisbane Water.

c) *In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:*

- i) *is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction; or*
- ii) *is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.*

Not Applicable.

d) *In relation to the habitat of a threatened species, population or ecological community:*

- i) *the extent to which habitat is likely to be removed or modified as a result of the action proposed; and*
- ii) *whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action; and*
- iii) *the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.*

Habitat for *Posidonia australis* populations in NSW is restricted to soft sedimentary subtidal environments, usually sandy, in the protected waters of marine embayments and marine-dominated coastal lakes, from Twofold Bay in the south to Wallis Lake in the north (West *et al.* 1985, West *et al.* 1989). Threats to *Posidonia australis* habitat relate primarily to physical damage to the beds themselves and introduction of the invasive alga, *Caulerpa taxifolia*. As outlined in (b) the proposal would not result in the removal, modification, fragmentation or isolation of habitat important for the persistence of the population.

e) *Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).*

No critical habitat has been declared for this endangered population.

f) *Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.*

No recovery plan or threat abatement plan has been prepared for this endangered population.

g) Whether the action proposed constitutes or is part of a key threatening process (KTP) or is likely to result in the operation of, or increase the impact of, a KTP.

The proposal has potential to result in the operation of ‘the introduction of non-indigenous fish and marine vegetation to the coastal waters of NSW’. (FM Act). Boats can act as vectors for marine pests and algae which can be transported via anchor chains and fishing gear. The noxious algae *Caulerpa taxifolia* is of particular concern as it has been observed within the study area, is easily spread, can grow rapidly and may potentially outcompete native seagrasses.

Conclusion:

The proposal would not result in any direct impacts to the Brisbane Water population of *Posidonia australis* such that a viable local population of the species is likely to be placed at risk of extinction. Any indirect impacts would be negligible and mitigated through the implementation of a construction management plan. No significant impact on *Posidonia* beds would be expected and no species impact statement is recommended.

Appendix 2. ‘Assessment of Significance’ for Threatened Species, Populations and Communities Protected Under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act).

MIGRATORY ESTUARINE BIRDS

There are 23 species of estuarine birds listed as ‘migratory’ under the Commonwealth EPBC Act (including sandpipers, sanderlings, terns, snipes, plovers, curlews and whimbrels among others) which are known to or likely to occur within Brisbane Water and have not already been assessed under the State Assessment of Significance (**Appendix 1**). For the purposes of this assessment they have been grouped because of their similar habitat and food requirements.

Species Group:

Shorebirds

- Common sandpiper (*Actitis hypoleucos*)
- Ruddy turnstone (*Arenaria interpres*)
- Sharp-tailed sandpiper (*Calidris acuminata*)
- Red knot (*Calidris canutus*)
- Curlew sandpiper (*Calidris ferruginea*)
- Red-necked stint (*Calidris ruficollis*)
- Double-banded plover (*Charadrius bicinctus*)
- Latham's snipe (*Gallinago hardwickii*)
- Swinhoe's snipe (*Gallinago megala*)
- Pin-tailed snipe (*Gallinago stenura*)
- Grey-tailed tattler (*Heteroscelus brevipes*)
- Bar-tailed godwit (*Limosa lapponica*)
- Eastern curlew (*Numenius madagascariensis*)
- Little curlew (*Numenius minutus*)
- Whimbrel (*Numenius phaeopus*)
- Common greenshank (*Tringa nebularia*)
- Marsh sandpiper (*Tringa stagnatilis*)
- Pacific golden plover (*Pluvialis fulva*)
- Grey plover (*Pluvialis squatarola*)

Diving Birds

- Caspian tern (*Sterna caspia*)

- Common tern (*Sterna hirundo*)

Raptors

- Great egret (*Ardea alba*)
- White-bellied sea-eagle (*Haliaeetus leucogaster*)

Status: Migratory –Part 13, Section 209(3) EPBC Act

Significant Impact Criteria:

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

a) Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species.

Shore birds or 'waders' are those birds commonly found on coastal shores, including beaches, rocky shores, mudflats, tidal wetlands and lagoons. These include plovers and sandpipers in the families Charadriidae and Scolopacidae, curlews, snipes, stints and godwits among others (Australian Museum 2010). Wading birds feed on marine invertebrates (including molluscs, worms and crustaceans), small fish that live within intertidal sand and mudflats. Small reptiles, earthworms, seeds and vegetation may also form part of their diet. Waders feed in the shallows or over exposed mud by probing their long slender bills into the substratum. Bill length, legs, body-structure, size and foraging techniques may subtly or markedly differ between groups of waders (Pizzey and Knight 1997). Important nesting areas may include sandbanks, sandpits, islands in estuaries, mangroves and riparian vegetation adjacent to the waterway. Nesting often takes place close to the ground which can make these birds vulnerable to disturbance.

Terns are diving birds that plunge into the water to catch fish or other food. They may enter the water from flight, or dive from the surface of the water.

Raptors are predatory birds that use their clawed feet rather than their beaks to catch their prey. Estuaries in NSW are important habitat to the white-bellied sea eagle where it may reside, forage and breed (DEWHA 2010a). The white-bellied sea eagle generally forages over large expanses of open water. The white-bellied sea eagle feeds opportunistically on a variety of fish, birds, reptiles, mammals and crustaceans, and on carrion and offal. It nests in large trees in forest or woodland often adjacent to a waterway. The main threats to the white-bellied sea eagle are the loss of habitat due to land development, and the disturbance of nesting pairs by human activity. The white-bellied sea eagle is sensitive to disturbance

when nesting, especially during the early stages of the breeding season, and may desert nests and young if confronted by humans or exposed to human activity (Clunie 1994).

The proposed marina will not impinge upon intertidal flats which is an important feeding habitat for wading birds. Given the relatively small area of waterway, it would be highly unlikely to affect the feeding habitat of either of the diving terns or the raptors.

Hence, it is unlikely that the proposal would cause adverse impacts that would result in a viable local population of wading birds being placed at risk of extinction.

b) Result in invasive species that are harmful to the migratory species becoming established in an area of important habitat for the migratory species.

No invasive species harmful to estuarine birds are likely to be released or have their populations enhanced as a consequence of the proposal.

c) Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

It is possible that noise and vibration caused during construction works (particularly pile driving) may cause short-term disturbance to birds roosting or feeding nearby. Disturbance from noise or vibration during construction would, however, be temporary, localised and at worst would result in birds moving to similar roosting areas nearby. Furthermore, the area within the vicinity of the proposed marina is relatively sparse in terms of vegetation suitable for roosting habitat.

Contamination of benthic sediments within the footprint of the proposed marina may be an issue if existing sediments are disturbed during pile driving and/or from the corrosion of anti-fouling agents used on boat hulls and jetty piles. Contaminants may be ingested by benthic invertebrates and assimilated up the food chain to shorebirds, diving birds and raptors which feed upon benthic animals or small fish. However, analysis of existing sediments indicate that disturbance of the existing sediments would not pose a contamination risk. All vessels berthed at the proposed marina would be less than 25 m length and hence are not permitted to use tin based anti-fouling paints. Copper based paints are less damaging to the marine environment and do not readily bioaccumulate (Clark 1997). Given the relatively small-scale of the proposed marina the contamination impacts are likely to be negligible and impacts on wading birds, diving birds and raptors would not occur to the extent that it would seriously disrupt the lifecycle of an ecologically significant proportion of a population of a migratory species.

Conclusion:

It is not considered that the proposed marina at Koolewong would have a significant impact on migratory wading birds, diving birds or raptors protected under the EPBC Act. The proposal would not have any significant direct or indirect impacts on the habitat of these birds or result in invasive species that are harmful to wading birds becoming established in estuaries. Potential impacts during construction of the proposed marina would have a minimal short term impact on any migratory birds roosting or feeding in the area. There are no known breeding or nesting areas known to occur within the study area. A referral is therefore not recommended.

Appendix 3: Geographical positions of sites where water and sediment were sampled (2 replicates at each site). WGS 84 Datum used in UTS/UTM projection, Zone 54H.

Site Number	Easting	Northing
S1	344051	6295132
S2	344084	6295153
S3	344144	6295246
S4	344077	6295315
S5	344038	6295238
S6	344390	6295354
S7	344095	6295080

Appendix 4: Results of pair-wise Permanova+ tests for significant factors for probe data, sampled on 7/3/2011. Sites = Si and water depth = De. Groups = sites compared; *t* = test statistic; P(perm) = probability ($\alpha = 0.05$) based on actual number of permutations available; P(MC) = probability based on Monte Carlo simulations.

Temperature - comparison of sites

Groups	<i>t</i>	P(perm)	P(MC)
S1, S2	2.9423	0.1104	0.0290
S1, S3	2.8936	0.0844	0.0252
S1, S4	2.5648	0.0844	0.0404
S1, S5	2.1006	0.1098	0.0756
S1, S6	4.2053	0.0318	0.0058
S1, S7	8.3429	0.0282	0.0002
S2, S3	Negative		
S2, S4	0.2677	0.9730	0.8032
S2, S5	1.4862	0.4032	0.1788
S2, S6	14.7710	0.0320	0.0002
S2, S7	17.6120	0.0274	0.0002
S3, S4	0.2490	0.8776	0.8034
S3, S5	1.3718	0.2936	0.2092
S3, S6	6.1721	0.0246	0.0010
S3, S7	15.3630	0.0286	0.0002
S4, S5	0.8392	0.4122	0.4150
S4, S6	2.9801	0.0284	0.0256
S4, S7	10.5490	0.0292	0.0002
S5, S6	4.3758	0.0288	0.0050
S5, S7	11.9470	0.0312	0.0002
S6, S7	14.1510	0.0310	0.0002

Salinity - comparison of sites

Groups	<i>t</i>	P(perm)	P(MC)
S1, S2	4.9652	0.0032	0.0072
S1, S3	4.5766	0.0146	0.0094
S1, S4	19.0530	0.0022	0.0004
S1, S5	22.7680	0.0024	0.0002
S1, S6	18.9950	0.0028	0.0002
S1, S7	24.3180	0.0092	0.0002
S2, S3	1.9242	0.1256	0.1288
S2, S4	1.1704	0.2874	0.3070
S2, S5	0.8221	0.5086	0.4604
S2, S6	1.3483	0.1866	0.2644
S2, S7	2.1723	0.0220	0.1062
S3, S4	1.7823	0.0928	0.1550
S3, S5	2.4000	0.0198	0.0772
S3, S6	1.4926	0.1470	0.2052
S3, S7	7.0564	0.0120	0.0028
S4, S5	4.2426	0.0196	0.0150
S4, S6	1.7321	0.1834	0.1616
S4, S7	13.6710	0.0090	0.0002
S5, S6	9.0000	0.0216	0.0004
S5, S7	13.0000	0.0076	0.0004
S6, S7	14.7950	0.0092	0.0002

continued...

Appendix 4, continued

pH - comparison of sites within each depth
 Term 'SixDe' for pairs of levels of factor 'Site'
 Within level 'S' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	7.6026	0.3254	0.0152
S1, S3	2.4962	0.3330	0.1312
S1, S4	1.3416	0.6704	0.3104
S1, S5	0.4472	1.0000	0.6984
S1, S6	1.3416	0.6696	0.3040
S1, S7	2.8284	0.3390	0.1026
S2, S3	2.5298	0.3198	0.1246
S2, S4	9.8995	0.3388	0.0098
S2, S5	11.3140	0.3382	0.0056
S2, S6	9.8995	0.3286	0.0082
S2, S7	4.0249	0.3408	0.0550
S3, S4	1.8974	0.3366	0.2032
S3, S5	2.5298	0.3374	0.1252
S3, S6	1.8974	0.3410	0.1988
S3, S7	0.2774	1.0000	0.8080
S4, S5	1.4142	0.6662	0.3102
S4, S6	0.0000	1.0000	1.0000
S4, S7	2.2361	0.3284	0.1568
S5, S6	1.4142	0.6592	0.2730
S5, S7	3.1305	0.3318	0.0924
S6, S7	2.2361	0.3422	0.1586

Within level 'B' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	4.0249	0.3378	0.0616
S1, S3	8.4971	0.3296	0.0156
S1, S4	0.4932	1.0000	0.6712
S1, S5	3.0000	0.3214	0.0966
S1, S6	2.8284	0.3258	0.1086
S1, S7	9.0000	0.3392	0.0144
S2, S3	3.5355	0.3304	0.0646
S2, S4	1.8974	0.3338	0.1962
S2, S5	3.0000	0.3362	0.0942
S2, S6	5.8138	0.3416	0.0298
S2, S7	9.0000	0.3360	0.0136
S3, S4	3.4785	0.3200	0.0780
S3, S5	8.0000	0.3302	0.0148
S3, S6	10.2860	0.3320	0.0092
S3, S7	14.0000	0.3346	0.0064
S4, S5	1.0000	1.0000	0.4214
S4, S6	0.1644	1.0000	0.8770
S4, S7	1.0000	1.0000	0.4264
S5, S6	7.0000	0.3284	0.0180
S5, S7	Denominator is 0		
S6, S7	5.0000	0.3300	0.0440

continued...

Appendix 4, continued

ORP - comparison of sites within each depth

Term 'SixDe' for pairs of levels of factor 'Site'

Within level 'S' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	36.0000	0.3310	0.0004
S1, S3	Denominator is 0		
S1, S4	23.0000	0.3286	0.0024
S1, S5	Denominator is 0		
S1, S6	Denominator is 0		
S1, S7	10.0000	0.3276	0.0120
S2, S3	19.0000	0.3340	0.0028
S2, S4	42.4850	0.3432	0.0016
S2, S5	41.0000	0.3348	0.0008
S2, S6	38.0000	0.3430	0.0008
S2, S7	32.5270	0.3432	0.0010
S3, S4	57.0000	0.3322	0.0004
S3, S5	Denominator is 0		
S3, S6	Denominator is 0		
S3, S7	27.0000	0.3352	0.0024
S4, S5	13.0000	0.3278	0.0058
S4, S6	19.0000	0.3394	0.0020
S4, S7	1.3416	0.6698	0.2972
S5, S6	Denominator is 0		
S5, S7	5.0000	0.3250	0.0366
S6, S7	8.0000	0.3272	0.0126

Within level 'B' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	29.0690	0.3248	0.0008
S1, S3	8.3843	0.3352	0.0116
S1, S4	9.8995	0.3302	0.0100
S1, S5	5.0000	0.3248	0.0380
S1, S6	2.8284	0.3334	0.1074
S1, S7	15.0000	0.3310	0.0042
S2, S3	18.3410	0.3358	0.0036
S2, S4	35.3300	0.3312	0.0016
S2, S5	35.0000	0.3450	0.0016
S2, S6	30.8580	0.3220	0.0010
S2, S7	40.0000	0.3256	0.0008
S3, S4	6.0828	0.3294	0.0270
S3, S5	7.6667	0.3322	0.0168
S3, S6	7.7268	0.3310	0.0204
S3, S7	6.0000	0.3452	0.0268
S4, S5	9.0000	0.3334	0.0122
S4, S6	7.0711	0.3394	0.0208
S4, S7	1.0000	1.0000	0.4224
S5, S6	1.0000	1.0000	0.4102
S5, S7	Denominator is 0		
S6, S7	11.0000	0.3324	0.0090

continued...

Appendix 4, continued

DO mg/L - comparison of sites within each depth

Term 'SixDe' for pairs of levels of factor 'Site'

Within level 'S' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	25.2000	0.3306	0.0018
S1, S3	15.6220	0.3314	0.0044
S1, S4	13.8880	0.3330	0.0044
S1, S5	15.6890	0.3420	0.0058
S1, S6	7.4550	0.3210	0.0210
S1, S7	7.4885	0.3490	0.0146
S2, S3	95.0000	0.3424	0.0002
S2, S4	35.6670	0.3268	0.0010
S2, S5	46.0000	0.3440	0.0006
S2, S6	23.0000	0.3334	0.0012
S2, S7	25.8000	0.3426	0.0018
S3, S4	3.7947	0.3284	0.0634
S3, S5	1.3416	0.6606	0.3142
S3, S6	9.3338	0.3292	0.0138
S3, S7	19.4240	0.3372	0.0016
S4, S5	4.1603	0.3460	0.0528
S4, S6	7.0905	0.3352	0.0216
S4, S7	18.3040	0.3208	0.0026
S5, S6	9.4779	0.3322	0.0106
S5, S7	19.4940	0.3328	0.0016
S6, S7	13.6530	0.3464	0.0060

Within level 'B' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	7.1296	0.3344	0.0202
S1, S3	7.0298	0.3362	0.0160
S1, S4	6.2353	0.3452	0.0216
S1, S5	21.3680	0.3374	0.0024
S1, S6	1.8439	0.3266	0.2052
S1, S7	8.3969	0.3304	0.0136
S2, S3	3.4356	0.3310	0.0734
S2, S4	2.1062	0.3416	0.1776
S2, S5	0.5249	1.0000	0.6502
S2, S6	6.8616	0.3368	0.0224
S2, S7	11.3990	0.3358	0.0086
S3, S4	1.3741	0.6568	0.3018
S3, S5	6.9285	0.3226	0.0224
S3, S6	7.0711	0.3402	0.0174
S3, S7	11.4780	0.3394	0.0068
S4, S5	2.8041	0.3404	0.1024
S4, S6	5.9341	0.3416	0.0288
S4, S7	11.0310	0.3200	0.0066
S5, S6	37.6960	0.3306	0.0010
S5, S7	15.8810	0.3256	0.0038
S6, S7	9.3127	0.3250	0.0116

continued...

Appendix 4, continued

DO% - comparison of sites within each depth

Term 'SixDe' for pairs of levels of factor 'Site'

Within level 'S' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	19.0000	0.3274	0.0020
S1, S3	1.5689	0.3354	0.2610
S1, S4	11.0000	0.3268	0.0070
S1, S5	13.0000	0.3328	0.0052
S1, S6	9.0000	0.3342	0.0132
S1, S7	7.0000	0.3500	0.0176
S2, S3	2.2000	0.3328	0.1636
S2, S4	Denominator is 0		
S2, S5	Denominator is 0		
S2, S6	Denominator is 0		
S2, S7	Denominator is 0		
S3, S4	0.6000	1.0000	0.6014
S3, S5	1.0000	1.0000	0.4158
S3, S6	0.2000	1.0000	0.8592
S3, S7	3.0000	0.3298	0.0992
S4, S5	Denominator is 0		
S4, S6	Denominator is 0		
S4, S7	Denominator is 0		
S5, S6	Denominator is 0		
S5, S7	Denominator is 0		
S6, S7	Denominator is 0		

Within level 'B' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	7.6026	0.3280	0.0200
S1, S3	9.0000	0.3302	0.0116
S1, S4	4.9193	0.3356	0.0368
S1, S5	11.3140	0.3298	0.0090
S1, S6	3.0000	0.3340	0.0926
S1, S7	11.3140	0.3454	0.0072
S2, S3	4.0000	0.3338	0.0572
S2, S4	2.1213	0.3338	0.1742
S2, S5	0.4472	1.0000	0.6980
S2, S6	7.0000	0.3368	0.0212
S2, S7	14.7580	0.3362	0.0044
S3, S4	1.0000	1.0000	0.4258
S3, S5	7.0000	0.3382	0.0202
S3, S6	Denominator is 0		
S3, S7	25.0000	0.3400	0.0020
S4, S5	2.2361	0.3428	0.1564
S4, S6	4.0000	0.3402	0.0572
S4, S7	12.0750	0.3476	0.0056
S5, S6	13.0000	0.3364	0.0042
S5, S7	22.6270	0.3402	0.0026
S6, S7	19.0000	0.3284	0.0024

continued...

Appendix 4, continued

DO%: Within level 'S' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	1.6394	0.3370	0.2396
S1, S3	33.9880	0.3300	0.0008
S1, S4	6.2501	0.3366	0.0254
S1, S5	6.2550	0.3362	0.0274
S1, S6	4.9645	0.3266	0.0366
S1, S7	17.2340	0.3312	0.0040
S2, S3	0.3861	1.0000	0.7456
S2, S4	2.1610	0.3268	0.1552
S2, S5	1.8754	0.3402	0.2080
S2, S6	1.8619	0.3298	0.2104
S2, S7	5.4355	0.3374	0.0360
S3, S4	3.2645	0.3276	0.0794
S3, S5	2.9454	0.3408	0.1032
S3, S6	2.4701	0.3256	0.1426
S3, S7	25.5950	0.3344	0.0012
S4, S5	0.4514	0.6740	0.6938
S4, S6	0.2012	0.6652	0.8470
S4, S7	11.4210	0.3390	0.0068
S5, S6	0.1963	1.0000	0.8584
S5, S7	11.8880	0.3332	0.0060
S6, S7	9.4434	0.3392	0.0100

Within level 'B' of factor 'Depth'

Groups	t	P(perm)	P(MC)
S1, S2	4.3827	0.3386	0.0478
S1, S3	3.0633	0.3408	0.0898
S1, S4	6.2997	0.3266	0.0224
S1, S5	1.4410	0.3336	0.2878
S1, S6	1.2127	0.6738	0.3604
S1, S7	22.8560	0.3372	0.0014
S2, S3	4.3284	0.3354	0.0500
S2, S4	13.1480	0.3292	0.0094
S2, S5	0.5468	1.0000	0.6384
S2, S6	0.1362	1.0000	0.9070
S2, S7	34.2030	0.3338	0.0012
S3, S4	0.8061	0.6828	0.5124
S3, S5	3.1202	0.3266	0.0852
S3, S6	3.0907	0.3420	0.0954
S3, S7	10.1220	0.3408	0.0112
S4, S5	3.2515	0.3280	0.0870
S4, S6	3.3735	0.3294	0.0768
S4, S7	30.3720	0.3446	0.0010
S5, S6	0.3339	0.6800	0.7650
S5, S7	4.1152	0.3326	0.0576
S6, S7	5.4541	0.3422	0.0350

Appendix 5: Report from external testing laboratory on chemical composition of water samples collected in the vicinity of the proposed development, 7/3/2011.



REPORT OF ANALYSIS

Client : CARDNO ECOLOGY LAB 4 GREEN ST BROOKVALE NSW 2100	Job No. : CARD20/110308 Quote No. : QT-01843 Order No. : Date Sampled : Date Received : 8-MAR-2011 Sampled By :
Attention : CHRIS ROBERTS Project Name : KOOLEWONG MARINA Your Client Services Manager : BRIAN WOODWARD	Phone : (02) 94490151

Lab Reg No.	Sample Ref	Sample Description
N11/007807	S1R1	ESTUARINE WATER 7/3/11
N11/007808	S1R2	ESTUARINE WATER 7/3/11
N11/007809	S2R1	ESTUARINE WATER 7/3/11
N11/007810	S2R2	ESTUARINE WATER 7/3/11

Lab Reg No.		N11/007807	N11/007808	N11/007809	N11/007810	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
BTEX						
Benzene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Toluene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Ethyl Benzene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
m, p - Xylene	ug/L	< 2	< 2	< 2	< 2	NGCMS_1121
o - Xylene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Total Petroleum Hydrocarbons						
TPH C6 - C9	ug/L	< 25	< 25	< 25	< 25	NGCMS_1121
TPH C10 - C14	ug/L	< 25	< 25	< 25	< 25	NGCMS_1112
TPH C15 - C28	ug/L	< 100	< 100	< 100	< 100	NGCMS_1112
TPH C29 - C36	ug/L	< 100	< 100	< 100	< 100	NGCMS_1112
Surrogate						
Surrogate volatile Rec	%	97	101	100	99	
Dates						
Date extracted		8-MAR-2011	8-MAR-2011	8-MAR-2011	8-MAR-2011	
Date analysed		9-MAR-2011	9-MAR-2011	9-MAR-2011	9-MAR-2011	

Luke Baker, Analyst
Organics - NSW
Accreditation No. 198

17-MAR-2011

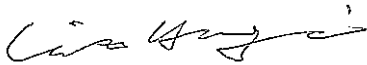
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1 Suakin Street, Pymble NSW 2073 Tel: + 61 2 9449 0111 Fax: + 61 2 9449 1653 www.measurement.gov.au

REPORT OF ANALYSIS

Page: 2 of 5
Report No. RN845653

Lab Reg No.		N11/007807	N11/007808	N11/007809	N11/007810	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
Trace Elements						
Antimony Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Arsenic Total	ug/L	1.1	1.3	1.4	1.4	NT2_47
Cadmium Total	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	NT2_47
Chromium Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Copper Total	ug/L	1.4	< 1	< 1	< 1	NT2_47
Lead Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Nickel Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Phosphorus Total	mg/L	0.027	0.045	0.024	0.024	NT2_47
Zinc Total	ug/L	16	2.5	2.5	< 1	NT2_47



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Inorganics - NSW
Accreditation No. 198

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Lab Reg No.		N11/007807	N11/007808	N11/007809	N11/007810	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
Miscellaneous						
Nitrogen - Total	mg/L	0.24	0.28	0.21	0.11	NW_B23



Wei Huang, Analyst
Inorganics - NSW
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17-MAR-2011

REPORT OF ANALYSIS

Page: 3 of 5

Report No. RN845653

Client : CARDNO ECOLOGY LAB 4 GREEN ST BROOKVALE NSW 2100	Job No. : CARD20/110308 Quote No. : QT-01843 Order No. : Date Sampled : Date Received : 8-MAR-2011 Sampled By :
Attention : CHRIS ROBERTS Project Name : KOOLEWONG MARINA Your Client Services Manager : BRIAN WOODWARD	Phone : (02) 94490151

Lab Reg No.	Sample Ref	Sample Description
N11/007811	S3R1	ESTUARINE WATER 7/3/11
N11/007812	S3R2	ESTUARINE WATER 7/3/11
N11/007813	S7R1	ESTUARINE WATER 7/3/11
N11/007814	S7R2	ESTUARINE WATER 7/3/11

Lab Reg No.		N11/007811	N11/007812	N11/007813	N11/007814	
Sample Reference	Units	S3R1	S3R2	S7R1	S7R2	Method
BTEX						
Benzene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Toluene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Ethyl Benzene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
m, p - Xylene	ug/L	< 2	< 2	< 2	< 2	NGCMS_1121
o - Xylene	ug/L	< 1	< 1	< 1	< 1	NGCMS_1121
Total Petroleum Hydrocarbons						
TPH C6 - C9	ug/L	< 25	< 25	< 25	< 25	NGCMS_1121
TPH C10 - C14	ug/L	< 25	< 25	< 25	< 25	NGCMS_1112
TPH C15 - C28	ug/L	< 100	< 100	< 100	< 100	NGCMS_1112
TPH C29 - C36	ug/L	< 100	< 100	< 100	< 100	NGCMS_1112
Surrogate						
Surrogate volatile Rec	%	102	108	106	97	
Dates						
Date extracted		8-MAR-2011	8-MAR-2011	8-MAR-2011	8-MAR-2011	
Date analysed		9-MAR-2011	9-MAR-2011	9-MAR-2011	9-MAR-2011	



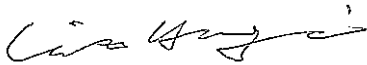
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REPORT OF ANALYSIS

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Report No. RN845653

Lab Reg No.		N11/007811	N11/007812	N11/007813	N11/007814	
Sample Reference	Units	S3R1	S3R2	S7R1	S7R2	Method
Trace Elements						
Antimony Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Arsenic Total	ug/L	1.2	1.3	1.1	1.3	NT2_47
Cadmium Total	ug/L	< 0.1	< 0.1	< 0.1	< 0.1	NT2_47
Chromium Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Copper Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Lead Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Nickel Total	ug/L	< 1	< 1	< 1	< 1	NT2_47
Phosphorus Total	mg/L	0.023	0.024	0.026	0.025	NT2_47
Zinc Total	ug/L	18	17	4.5	5.8	NT2_47



Lisa Liu, Analyst
Inorganics - NSW
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17-MAR-2011

Lab Reg No.		N11/007811	N11/007812	N11/007813	N11/007814	
Sample Reference	Units	S3R1	S3R2	S7R1	S7R2	Method
Miscellaneous						
Nitrogen - Total	mg/L	0.15	0.10	0.18	0.24	NW_B23



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17-MAR-2011

Total = acid extractable elements.

REPORT OF ANALYSIS

Page: 5 of 5
Report No. RN845653



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This Report supersedes reports: RN845495 RN845562 RN845568

Appendix 6: Report from external testing laboratory on grain size composition of sediments collected in the vicinity of the proposed development, 7/3/2011.

TEST CERTIFICATE



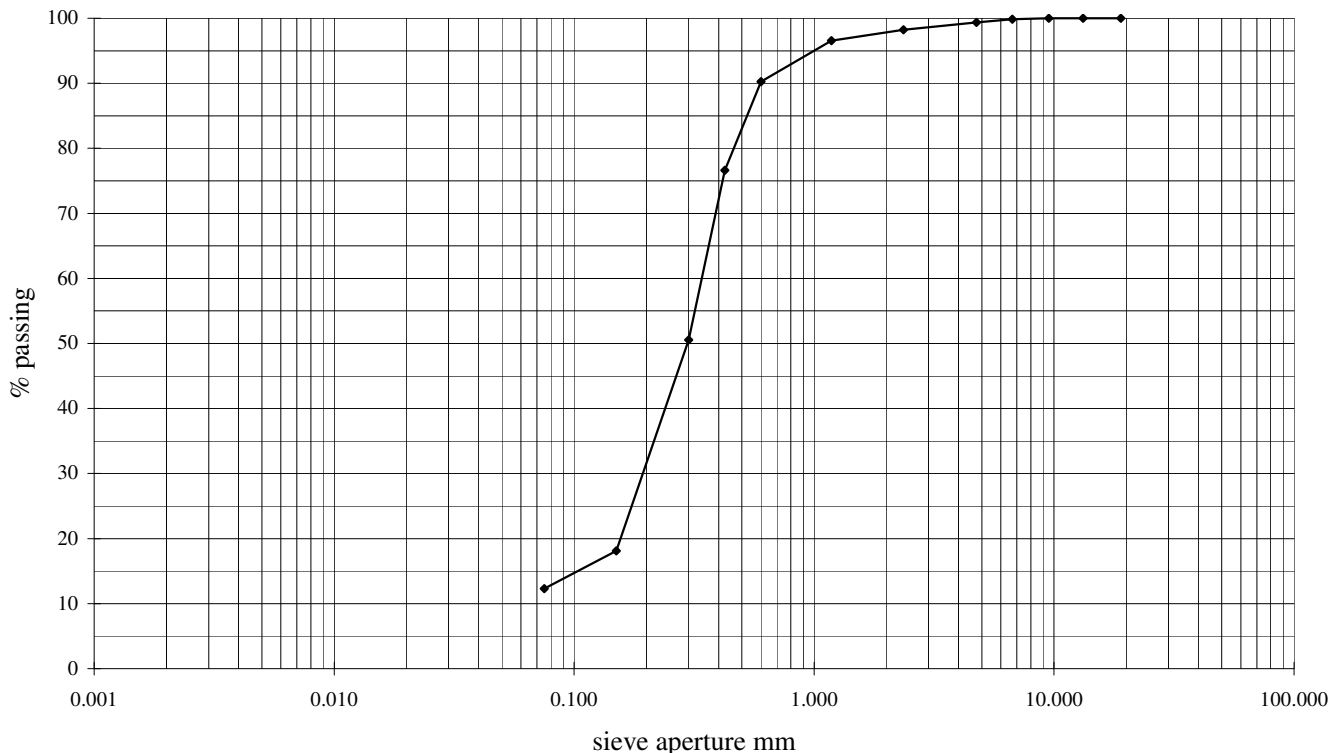
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64386
Sample Source: S1 R1 **Date Tested:** 14.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SAND: dark grey, fine to coarse sand, with silt, trace of fine gravel, non-plastic.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	97
75.0		0.600	90
63.0		0.425	77
53.0		0.300	51
37.5		0.150	18
26.5		0.075	12
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7	100	0.005	
4.75	99	0.002	
2.36	98		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None
Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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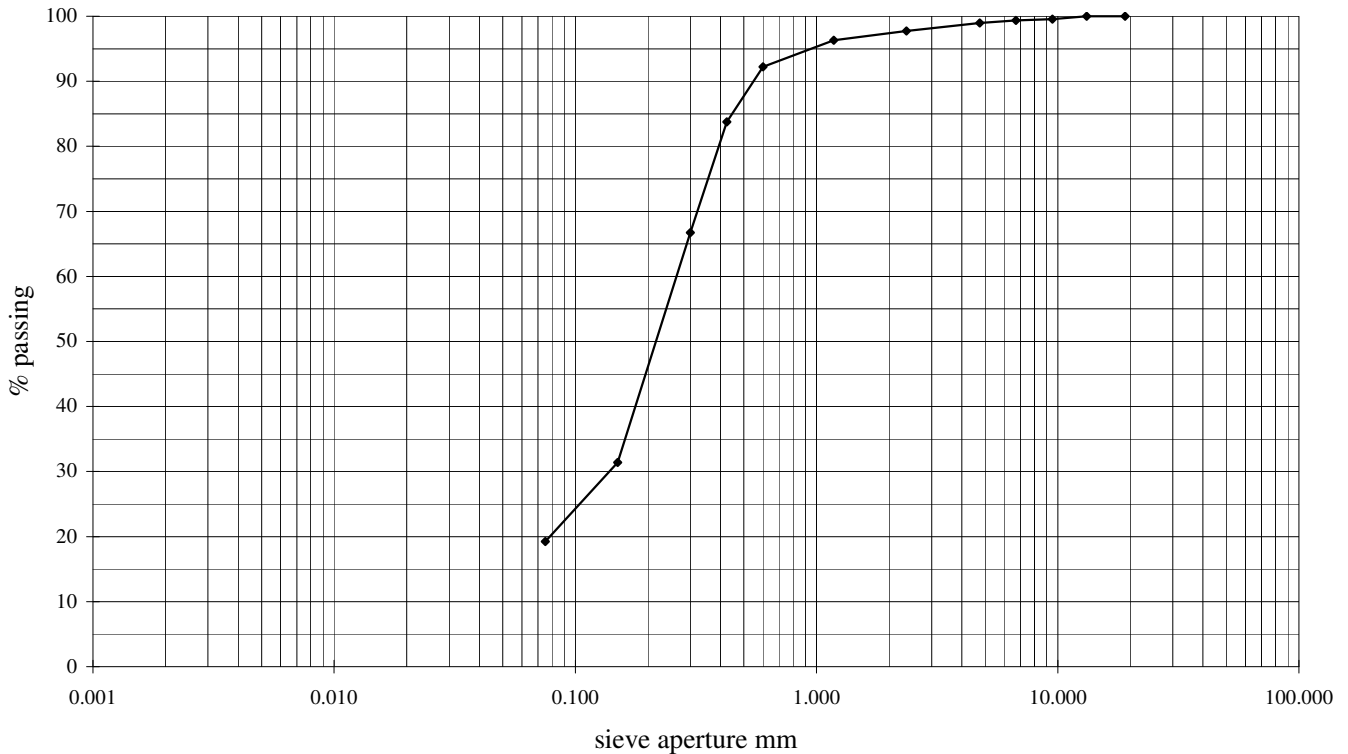
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64387
Sample Source: S1 R2 **Date Tested:** 14.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY SAND: dark-grey, fine to coarse sand, low plasticity, trace of fine gravel.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	96
75.0		0.600	92
63.0		0.425	84
53.0		0.300	67
37.5		0.150	31
26.5		0.075	19
19.0		0.050	
13.2		0.020	
9.5	100	0.010	
6.7	99	0.005	
4.75	99	0.002	
2.36	98		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:

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Date: 21.3.11



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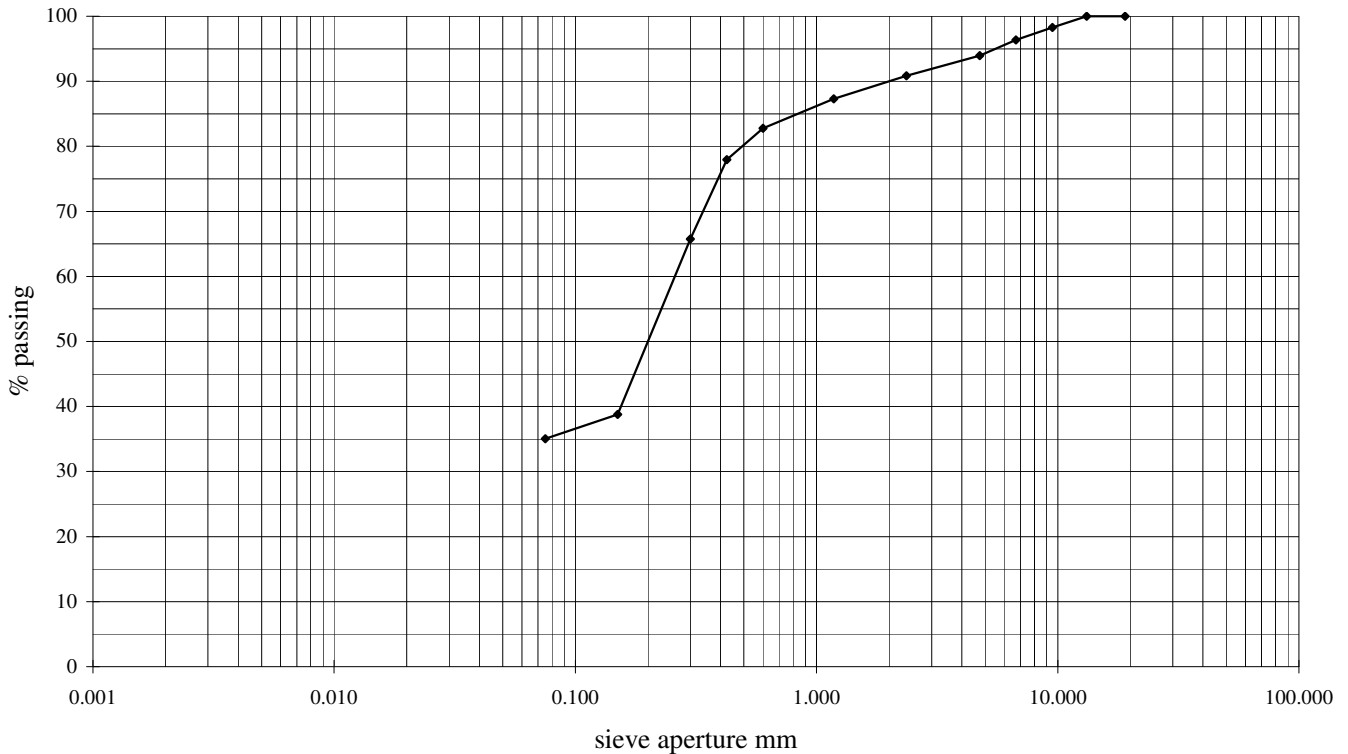
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64388
Sample Source: S2 R1 **Date Tested:** 14.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAYEY SAND: grey/brown, fine to coarse sand, medium plasticity, with fine to medium gravel.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	87
75.0		0.600	83
63.0		0.425	78
53.0		0.300	66
37.5		0.150	39
26.5		0.075	35
19.0		0.050	
13.2	100	0.020	
9.5	98	0.010	
6.7	96	0.005	
4.75	94	0.002	
2.36	91		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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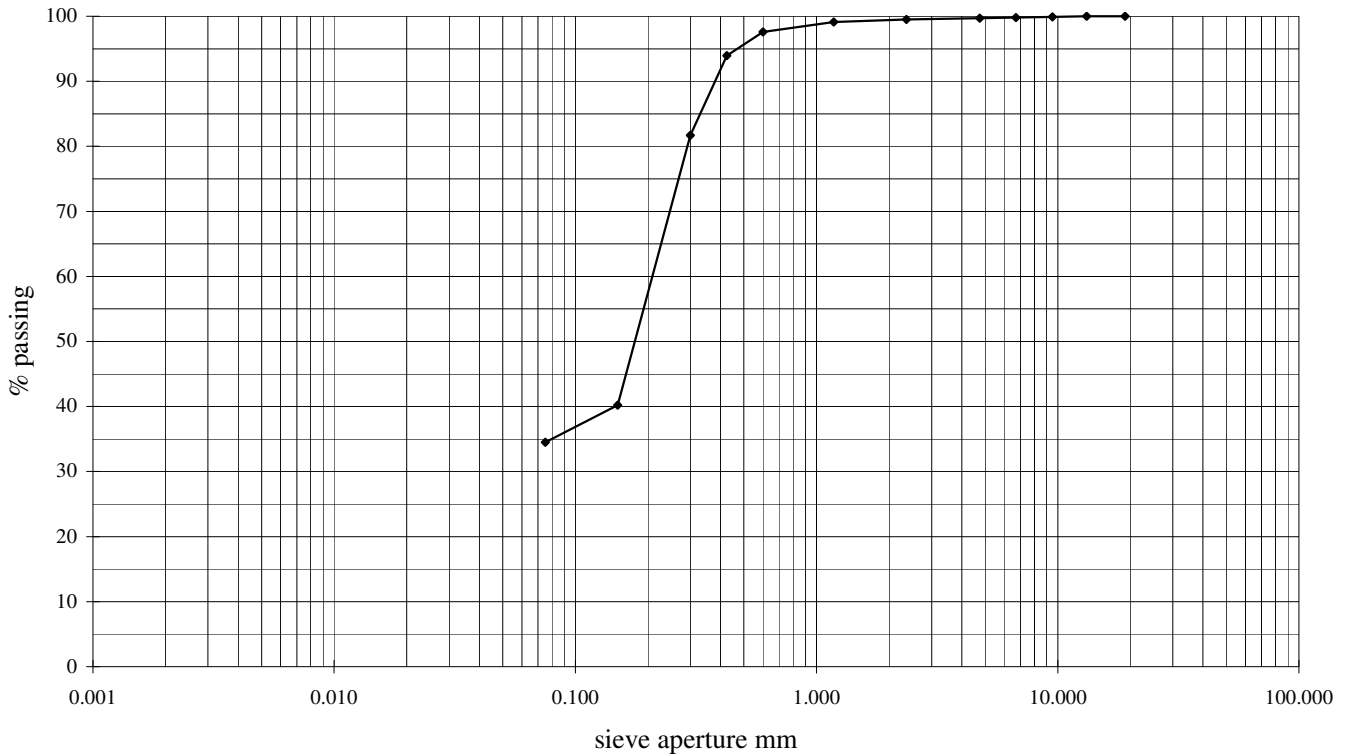
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Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64389
Sample Source: S2 R2 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAYEY SAND: dark grey, fine to coarse sand, low to medium plasticity, trace of fine gravel (shell).

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	99
75.0		0.600	98
63.0		0.425	94
53.0		0.300	82
37.5		0.150	40
26.5		0.075	34
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75	100	0.002	
2.36	99		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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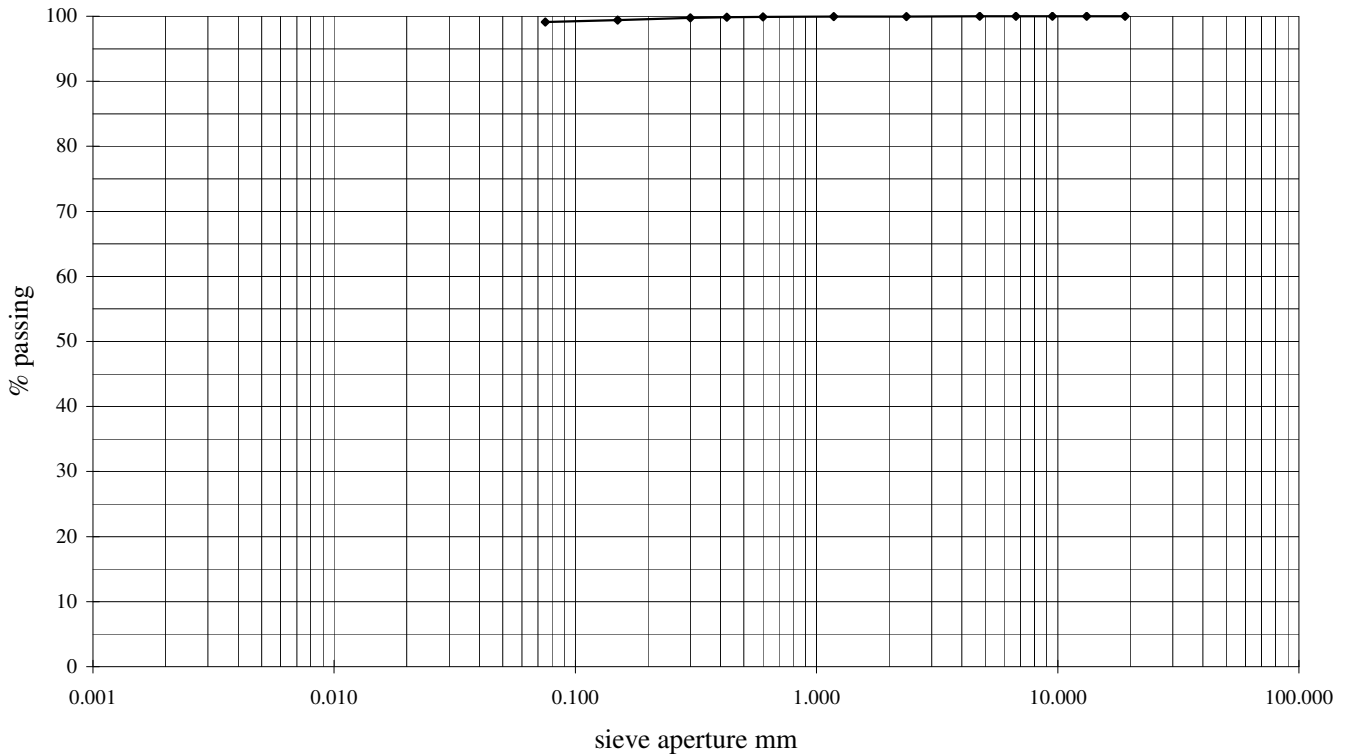
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64390
Sample Source: S3 R1 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: grey-brown, high plasticity, trace of fine to medium sand.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	
75.0		0.600	
63.0		0.425	
53.0		0.300	100
37.5		0.150	99
26.5		0.075	99
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75		0.002	
2.36			

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None
Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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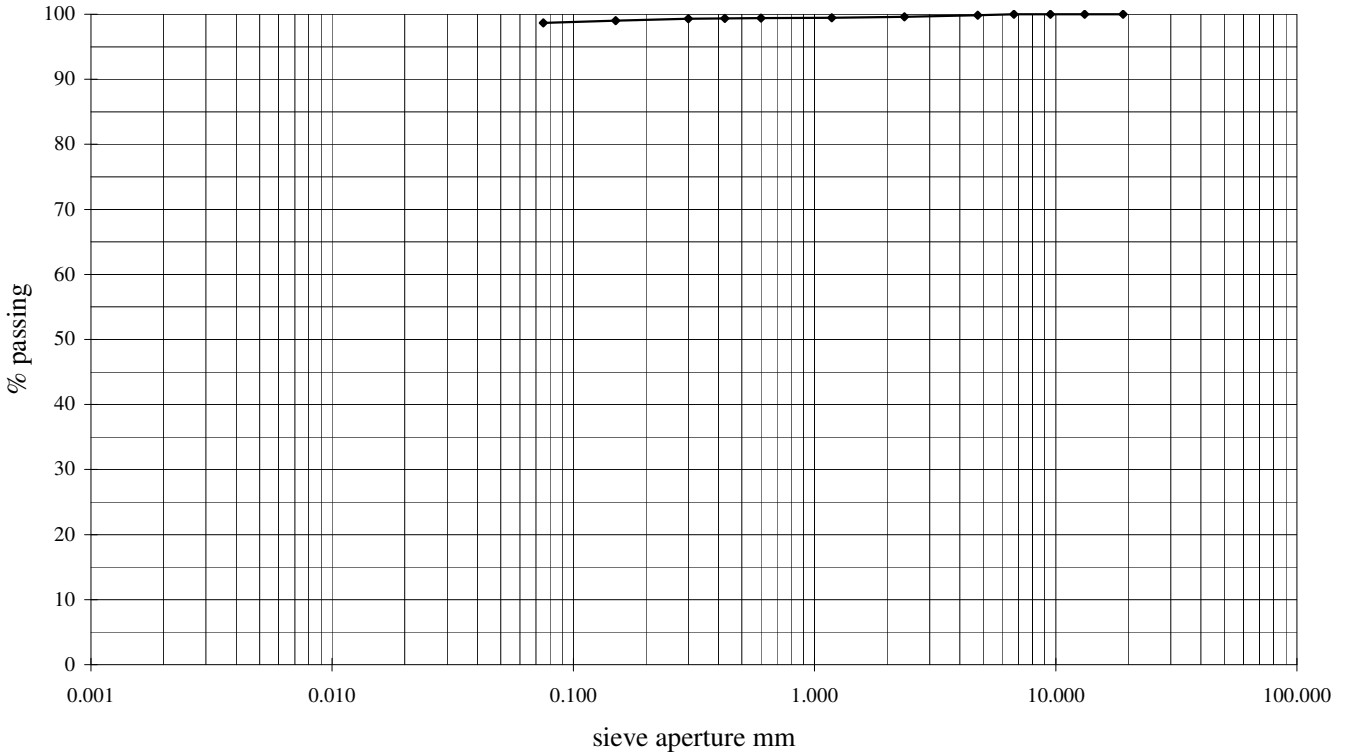
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64391
Sample Source: S3 R2 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: dark grey, high plasticity, trace fine to coarse sand.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	99
75.0		0.600	99
63.0		0.425	99
53.0		0.300	99
37.5		0.150	99
26.5		0.075	99
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75		0.002	
2.36	100		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:  Chris Lloyd

Date: 21.3.11



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TEST CERTIFICATE



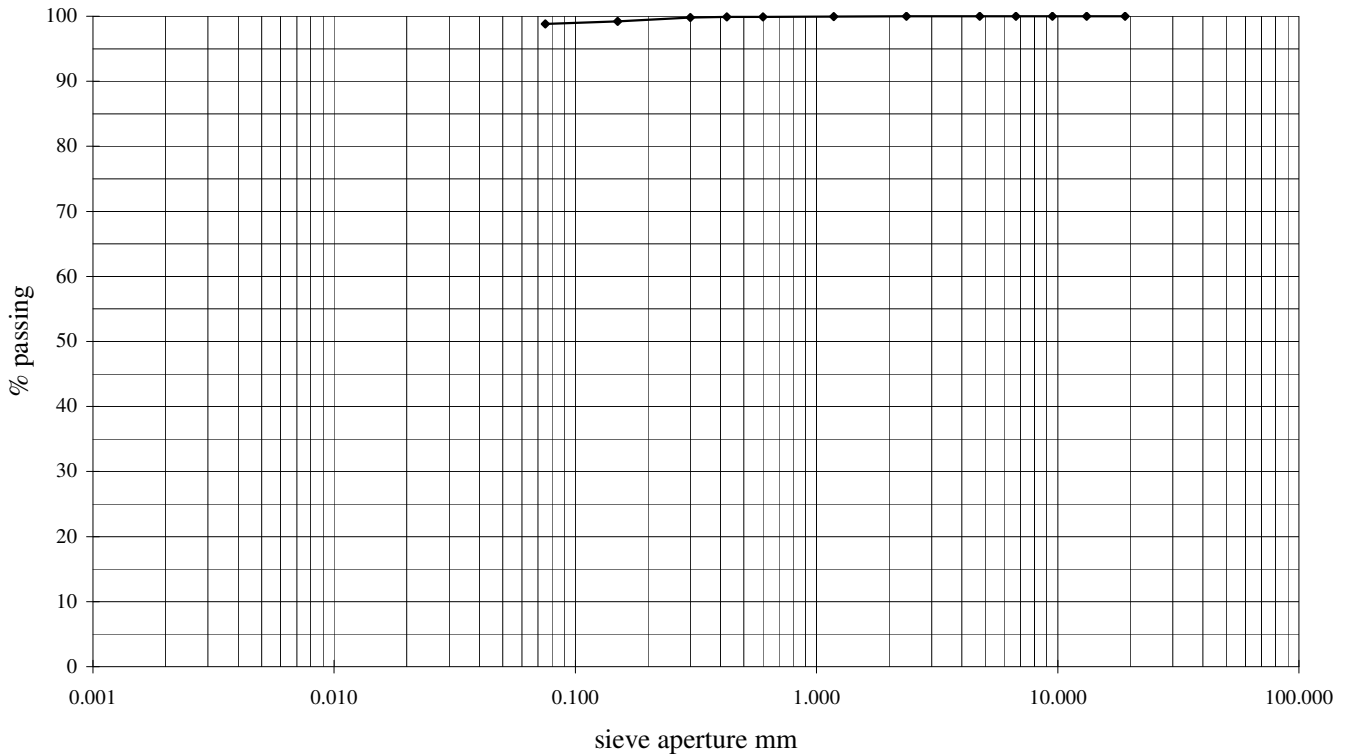
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 Unit 15, 33 Maddox Street
 (PO Box 6432)
 Alexandria NSW 2015
 Australia

ABN 44 000 964 278
 ph: +61 (0)2 8594 0481
 fax: +61 (0)2 8594 0499

PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64392
Sample Source: S4 R1 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: dark grey, high plasticity, trace of fine to medium sand.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	
75.0		0.600	
63.0		0.425	
53.0		0.300	100
37.5		0.150	99
26.5		0.075	99
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75		0.002	
2.36			

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None
Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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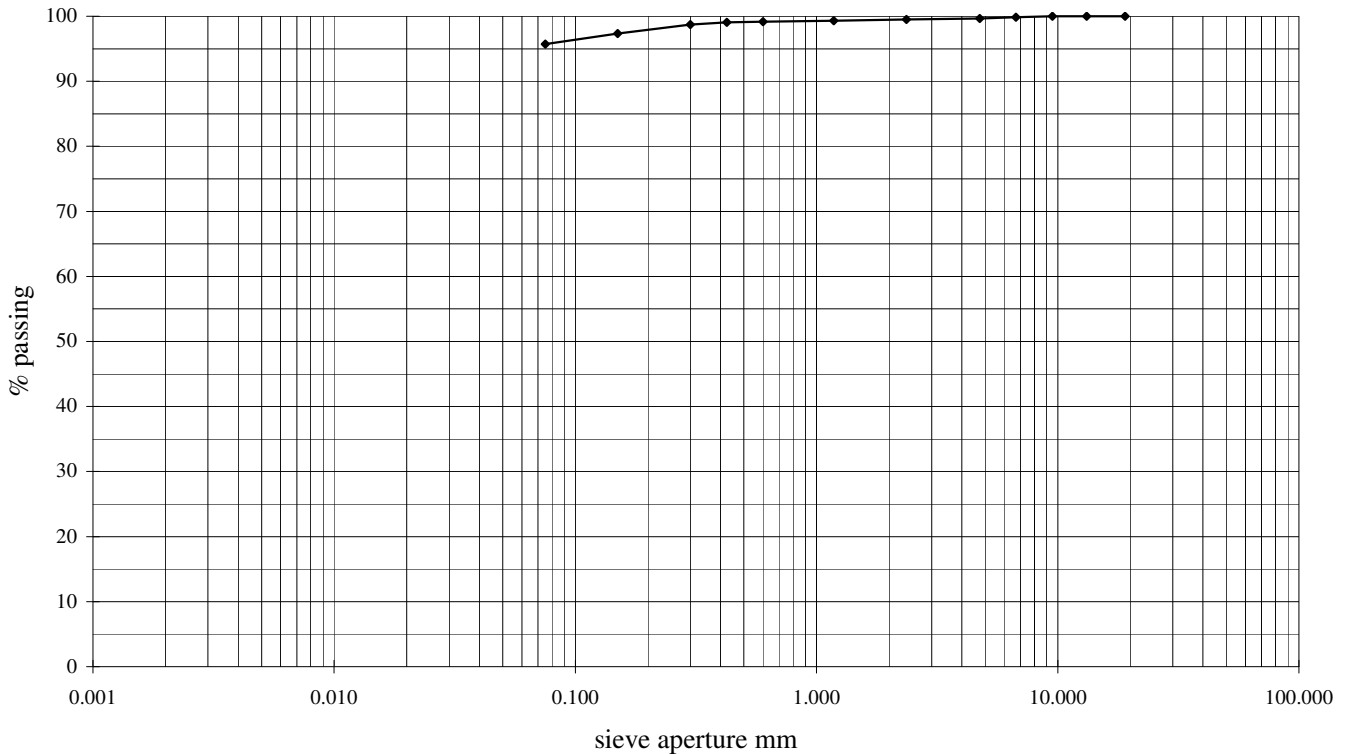
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64393
Sample Source: S4 R2 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: dark grey, high plasticity, trace of fine to coarse sand, trace of fine to medium gravel (shell).

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	99
75.0		0.600	99
63.0		0.425	99
53.0		0.300	99
37.5		0.150	97
26.5		0.075	96
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75	100	0.002	
2.36	99		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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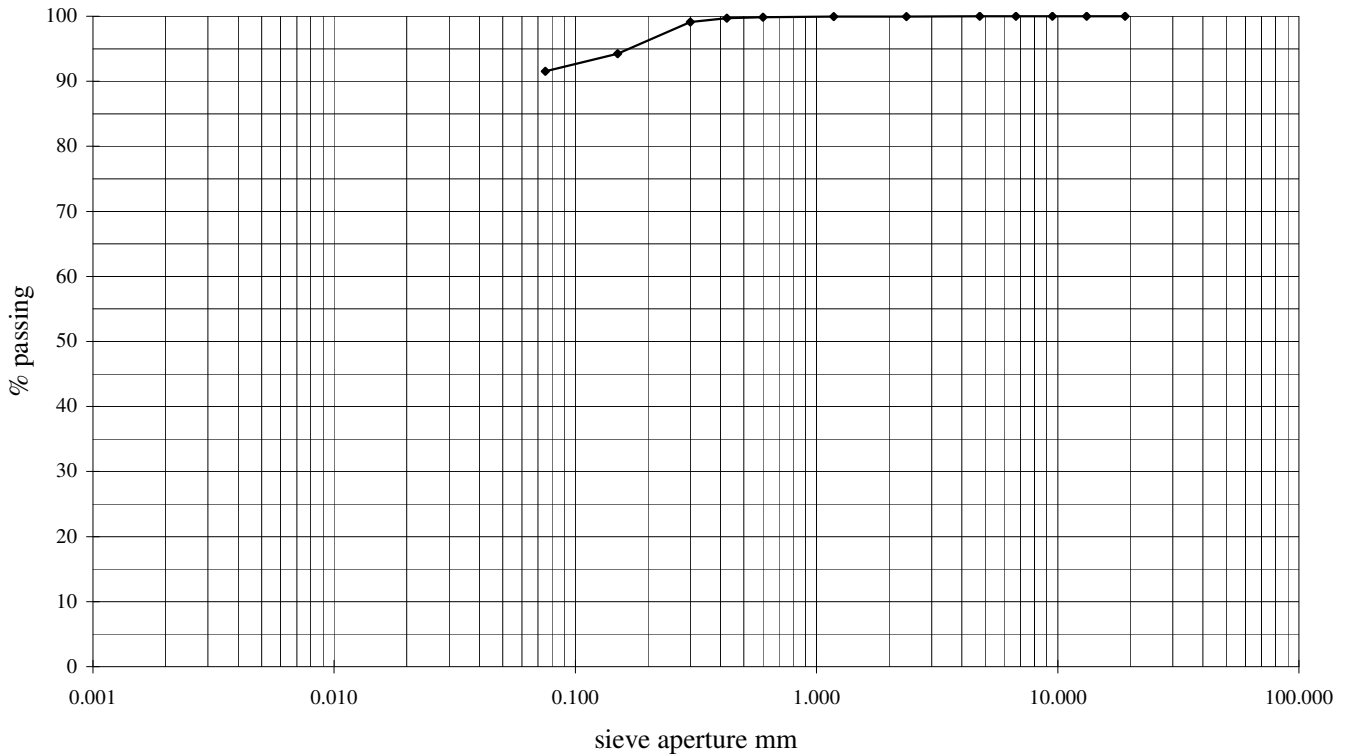
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64394
Sample Source: S5 R1 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: dark grey, high plasticity, trace of fine to medium sand.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	
75.0		0.600	
63.0		0.425	100
53.0		0.300	99
37.5		0.150	94
26.5		0.075	92
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75		0.002	
2.36			

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory: Chris Lloyd

Date: 21.3.11



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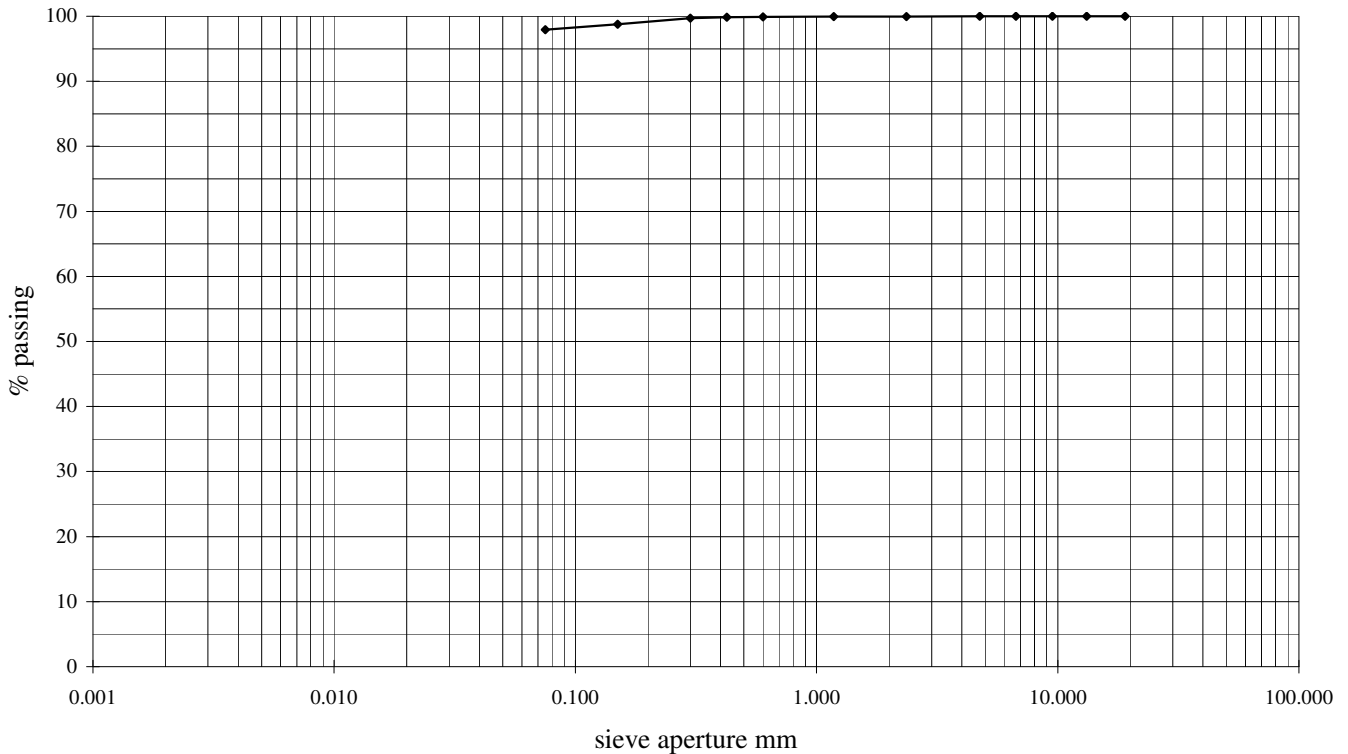
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64395
Sample Source: S5 R2 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY CLAY: dark grey, high plasticity, trace of fine sand.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	
75.0		0.600	
63.0		0.425	
53.0		0.300	100
37.5		0.150	99
26.5		0.075	98
19.0		0.050	
13.2		0.020	
9.5		0.010	
6.7		0.005	
4.75		0.002	
2.36			

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None
Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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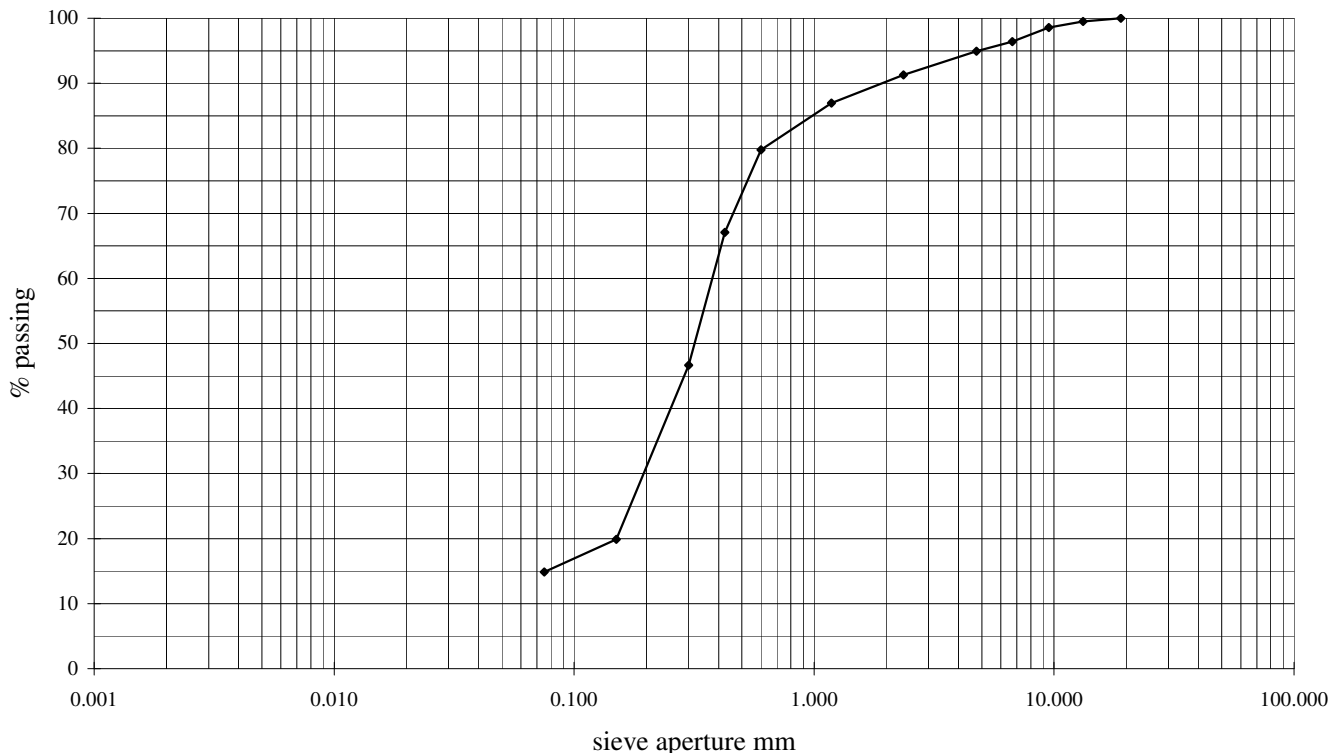
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64396
Sample Source: S7 R1 **Date Tested:** 14.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: SILTY SAND: dark grey/black, fine to coarse sand, trace of fine to medium gravel, non-plastic.

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	87
75.0		0.600	80
63.0		0.425	67
53.0		0.300	47
37.5		0.150	20
26.5		0.075	15
19.0		0.050	
13.2	100	0.020	
9.5	99	0.010	
6.7	96	0.005	
4.75	95	0.002	
2.36	91		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None
Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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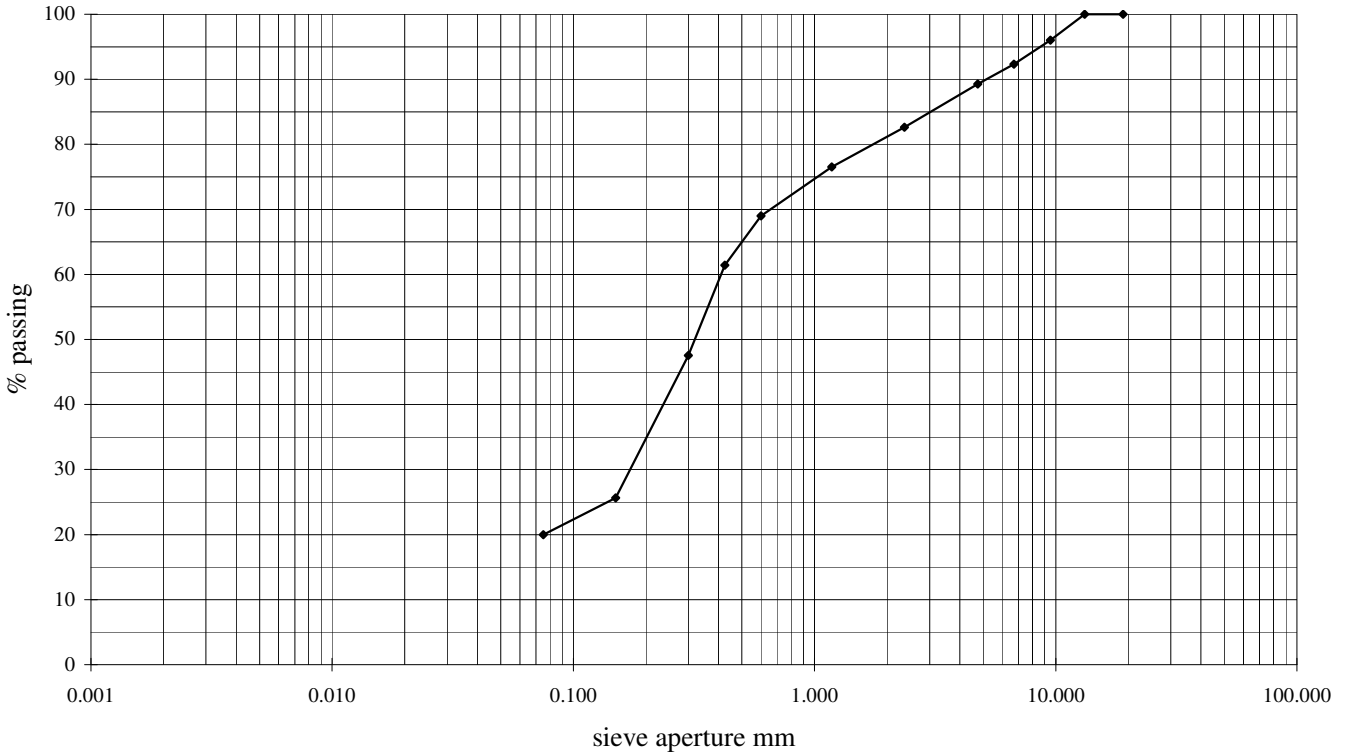
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PARTICLE SIZE DISTRIBUTION

Client: Cardno Ecology Lab
Address: 4 Green Street, Brookvale NSW 2100
Project: Koolewong Marina Job No: EL10110959
Test Method: AS 1289 3.6.1
Job Number: 031-757 **Lab Number:** 64397
Sample Source: S7 R2 **Date Tested:** 11.03.11
Sampled By: Client **Checked By:** CL



Clay	Silt	Sand	Gravel
------	------	------	--------

Sample Description: GRAVELLY SILTY SAND: dark grey/black, fine to coarse sand, low plasticity, fine to medium gravel (shell), (organic).

Sieve Size (mm)	% Passing	Sieve Size (mm)	% Passing
150.0		1.18	77
75.0		0.600	69
63.0		0.425	61
53.0		0.300	48
37.5		0.150	26
26.5		0.075	20
19.0		0.050	
13.2	100	0.020	
9.5	96	0.010	
6.7	92	0.005	
4.75	89	0.002	
2.36	83		

Hydrometer Type: N/A
Dispersant Type: N/A
Pretreatment: None
Loss on Pretreatment: None

Remarks:

Approved Signatory:

Chris Lloyd

Date: 21.3.11



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Appendix 7: Report from external testing laboratory on chemical composition of sediments collected in the vicinity of the proposed development, 7/3/2011.



REPORT OF ANALYSIS

Client : CARDNO ECOLOGY LAB 4 GREEN ST BROOKVALE NSW 2100	Job No. : CARD20/110308 Quote No. : QT-01843 Order No. : Date Sampled : Date Received : 8-MAR-2011 Sampled By :
Attention : CHRIS ROBERTS Project Name : KOOLEWONG MARINA Your Client Services Manager : BRIAN WOODWARD	Phone : (02) 94490151

Lab Reg No.	Sample Ref	Sample Description
N11/007795	S1R1	ESTUARINE SEDIMENT 7/3/11
N11/007796	S1R2	ESTUARINE SEDIMENT 7/3/11
N11/007797	S2R1	ESTUARINE SEDIMENT 7/3/11
N11/007798	S2R2	ESTUARINE SEDIMENT 7/3/11

Lab Reg No.		N11/007795	N11/007796	N11/007797	N11/007798	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
BTEX						
Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Toluene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Ethyl Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
m, p - Xylene	mg/kg	< 1	< 1	< 1	< 1	NGCMS_1121
o - Xylene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Total Petroleum Hydrocarbons						
TPH C6 - C9	mg/kg	< 25	< 25	< 25	< 25	NGCMS_1121
TPH C10 - C14	mg/kg	< 50	< 50	< 50	< 50	NGCMS_1112
TPH C15 - C28	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
TPH C29 - C36	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
Surrogate						
Surrogate volatile Rec	%	77	81	76	73	
Dates						
Date extracted		9-MAR-2011	9-MAR-2011	9-MAR-2011	9-MAR-2011	
Date analysed		11-MAR-2011	11-MAR-2011	11-MAR-2011	11-MAR-2011	

Luke Baker, Analyst
Organics - NSW
Accreditation No. 198

17-MAR-2011

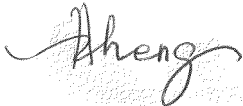
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REPORT OF ANALYSIS

Page: 2 of 7
Report No. RN845651

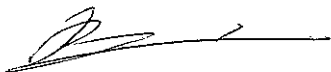
Lab Reg No.		N11/007795	N11/007796	N11/007797	N11/007798	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
Trace Elements						
Antimony	mg/kg	0.69	< 0.5	< 0.5	< 0.5	NT2_49
Arsenic	mg/kg	2.6	2.3	9.5	6.5	NT2_49
Cadmium	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1	NT2_49
Chromium	mg/kg	9.4	6.5	12	13	NT2_49
Copper	mg/kg	9.5	7.8	6	12	NT2_49
Lead	mg/kg	12	8.4	11	19	NT2_49
Mercury	mg/kg	0.03	0.03	0.10	0.18	NT2_49
Nickel	mg/kg	7.5	4.7	5.1	5	NT2_49
Selenium	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NT2_49
Zinc	mg/kg	45	39	27	47	NT2_49
Total Solids	%	69.7	69.4	46.1	56.9	NT2_49



Anna Zheng, Analyst
Inorganics - NSW
Accreditation No. 198

17-MAR-2011

Lab Reg No.		N11/007795	N11/007796	N11/007797	N11/007798	
Sample Reference	Units	S1R1	S1R2	S2R1	S2R2	Method
Miscellaneous						
Carbon - Total Organic	mg/kg	13400	11200	13700	14800	NW_S15



Wei Huang, Analyst
Inorganics - NSW
Accreditation No. 198

17-MAR-2011

REPORT OF ANALYSIS

Page: 3 of 7

Report No. RN845651

Client : CARDNO ECOLOGY LAB 4 GREEN ST BROOKVALE NSW 2100	Job No. : CARD20/110308 Quote No. : QT-01843 Order No. : Date Sampled : Date Received : 8-MAR-2011 Sampled By :
Attention : CHRIS ROBERTS Project Name : KOOLEWONG MARINA Your Client Services Manager : BRIAN WOODWARD	Phone : (02) 94490151

Lab Reg No.	Sample Ref	Sample Description
N11/007799	S3R1	ESTUARINE SEDIMENT 7/3/11
N11/007800	S3R2	ESTUARINE SEDIMENT 7/3/11
N11/007801	S4R1	ESTUARINE SEDIMENT 7/3/11
N11/007802	S4R2	ESTUARINE SEDIMENT 7/3/11

Lab Reg No.		N11/007799	N11/007800	N11/007801	N11/007802	
Sample Reference	Units	S3R1	S3R2	S4R1	S4R2	Method
BTEX						
Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Toluene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Ethyl Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
m, p - Xylene	mg/kg	< 1	< 1	< 1	< 1	NGCMS_1121
o - Xylene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Total Petroleum Hydrocarbons						
TPH C6 - C9	mg/kg	< 25	< 25	< 25	< 25	NGCMS_1121
TPH C10 - C14	mg/kg	< 50	< 50	< 50	< 50	NGCMS_1112
TPH C15 - C28	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
TPH C29 - C36	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
Surrogate						
Surrogate volatile Rec	%	77	76	74	73	
Dates						
Date extracted		9-MAR-2011	9-MAR-2011	9-MAR-2011	9-MAR-2011	
Date analysed		11-MAR-2011	11-MAR-2011	11-MAR-2011	11-MAR-2011	



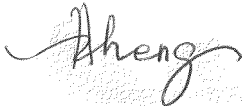
Luke Baker, Analyst
Organics - NSW
Accreditation No. 198

17-MAR-2011

REPORT OF ANALYSIS

Page: 4 of 7
Report No. RN845651

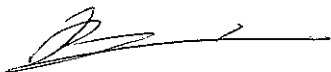
Lab Reg No.		N11/007799	N11/007800	N11/007801	N11/007802	
Sample Reference	Units	S3R1	S3R2	S4R1	S4R2	Method
Trace Elements						
Antimony	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NT2_49
Arsenic	mg/kg	13	12	12	15	NT2_49
Cadmium	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1	NT2_49
Chromium	mg/kg	34	36	34	32	NT2_49
Copper	mg/kg	27	30	28	19	NT2_49
Lead	mg/kg	47	47	45	41	NT2_49
Mercury	mg/kg	0.19	0.16	0.17	0.19	NT2_49
Nickel	mg/kg	14	14	13	13	NT2_49
Selenium	mg/kg	1.3	1.2	1.1	0.8	NT2_49
Zinc	mg/kg	130	140	130	100	NT2_49
Total Solids	%	28.9	29.8	29.9	35.8	NT2_49



Anna Zheng, Analyst
Inorganics - NSW
Accreditation No. 198

17-MAR-2011

Lab Reg No.		N11/007799	N11/007800	N11/007801	N11/007802	
Sample Reference	Units	S3R1	S3R2	S4R1	S4R2	Method
Miscellaneous						
Carbon - Total Organic	mg/kg	38100	33600	36800	30700	NW_S15



Wei Huang, Analyst
Inorganics - NSW
Accreditation No. 198

17-MAR-2011

REPORT OF ANALYSIS

Page: 5 of 7

Report No. RN845651

Client : CARDNO ECOLOGY LAB 4 GREEN ST BROOKVALE NSW 2100	Job No. : CARD20/110308 Quote No. : QT-01843 Order No. : Date Sampled : Date Received : 8-MAR-2011 Sampled By :
Attention : CHRIS ROBERTS Project Name : KOOLEWONG MARINA Your Client Services Manager : BRIAN WOODWARD	Phone : (02) 94490151

Lab Reg No.	Sample Ref	Sample Description
N11/007803	S5R1	ESTUARINE SEDIMENT 7/3/11
N11/007804	S5R2	ESTUARINE SEDIMENT 7/3/11
N11/007805	S7R1	ESTUARINE SEDIMENT 7/3/11
N11/007806	S7R2	ESTUARINE SEDIMENT 7/3/11

Lab Reg No.		N11/007803	N11/007804	N11/007805	N11/007806	
Sample Reference	Units	S5R1	S5R2	S7R1	S7R2	Method
BTEX						
Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Toluene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Ethyl Benzene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
m, p - Xylene	mg/kg	< 1	< 1	< 1	< 1	NGCMS_1121
o - Xylene	mg/kg	< 0.5	< 0.5	< 0.5	< 0.5	NGCMS_1121
Total Petroleum Hydrocarbons						
TPH C6 - C9	mg/kg	< 25	< 25	< 25	< 25	NGCMS_1121
TPH C10 - C14	mg/kg	< 50	< 50	< 50	< 50	NGCMS_1112
TPH C15 - C28	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
TPH C29 - C36	mg/kg	< 100	< 100	< 100	< 100	NGCMS_1112
Surrogate						
Surrogate volatile Rec	%	73	71	73	82	
Dates						
Date extracted		9-MAR-2011	9-MAR-2011	9-MAR-2011	9-MAR-2011	
Date analysed		11-MAR-2011	11-MAR-2011	11-MAR-2011	11-MAR-2011	



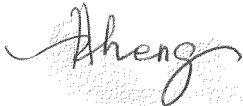
Luke Baker, Analyst
Organics - NSW
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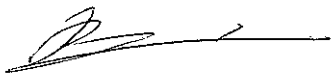
Lab Reg No.		N11/007803	N11/007804	N11/007805	N11/007806	
Sample Reference	Units	S5R1	S5R2	S7R1	S7R2	Method
Trace Elements						
Antimony	mg/kg	< 0.5	< 0.5	< 0.5	0.6	NT2_49
Arsenic	mg/kg	11	13	3.3	3.8	NT2_49
Cadmium	mg/kg	< 0.1	< 0.1	< 0.1	< 0.1	NT2_49
Chromium	mg/kg	29	31	11	18	NT2_49
Copper	mg/kg	24	25	11	25	NT2_49
Lead	mg/kg	39	39	10	14	NT2_49
Mercury	mg/kg	0.17	0.19	0.09	0.10	NT2_49
Nickel	mg/kg	12	12	9.1	20	NT2_49
Selenium	mg/kg	0.69	1.6	< 0.5	< 0.5	NT2_49
Zinc	mg/kg	110	120	47	97	NT2_49
Total Solids	%	36.2	22.4	71.5	63.2	NT2_49



Anna Zheng, Analyst
Inorganics - NSW
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Lab Reg No.		N11/007803	N11/007804	N11/007805	N11/007806	
Sample Reference	Units	S5R1	S5R2	S7R1	S7R2	Method
Miscellaneous						
Carbon - Total Organic	mg/kg	30400	34800	10800	22200	NW_S15



Wei Huang, Analyst
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All results are expressed on a dry weight basis.

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This Report supersedes reports: RN845491 RN845518 RN845561

Proposed Koolewong Marina Development - Aquatic Ecology Assessment

Prepared for ADW Johnson

Appendix 8: Results of pair-wise Permanova+ tests comparing sites for significant factors for sediment chemistry data, with samples collected on 7/3/2011. Groups = sites compared; *t* = test statistic; P(permutation) = probability ($\alpha = 0.05$) based on actual number of permutations available; P(MC) = probability based on Monte Carlo simulations.

Arsenic - comparison of sites

Groups	<i>t</i>	P(permutation)	P(MC)
S1, S2	3.6816	0.334	0.061
S1, S3	19.252	0.332	0.0044
S1, S4	7.3301	0.3324	0.019
S1, S5	9.4443	0.336	0.013
S1, S7	3.773	0.332	0.0556
S2, S3	2.846	0.3424	0.1114
S2, S4	2.5927	0.3416	0.1242
S2, S5	2.2188	0.333	0.1582
S2, S7	2.9263	0.331	0.105
S3, S4	0.63246	1	0.5906
S3, S5	0.44721	1	0.6978
S3, S7	16.01	0.3276	0.0032
S4, S5	0.83205	0.6678	0.4976
S4, S7	6.5431	0.347	0.0218
S5, S7	8.1977	0.3366	0.0174

Chromium - comparison of sites

Groups	<i>t</i>	P(permutation)	P(MC)
S1, S2	2.9665	0.3478	0.0978
S1, S3	15.357	0.3286	0.0044
S1, S4	14.222	0.336	0.0058
S1, S5	12.519	0.3356	0.006
S1, S7	1.7289	0.333	0.2242
S2, S3	20.125	0.3316	0.002
S2, S4	18.336	0.333	0.003
S2, S5	15.652	0.3288	0.0044
S2, S7	0.56569	1	0.6236
S3, S4	1.4142	0.674	0.2996
S3, S5	3.5355	0.3266	0.069
S3, S7	5.6318	0.3272	0.0292
S4, S5	2.1213	0.3376	0.1622
S4, S7	5.0823	0.332	0.0372
S5, S7	4.2582	0.3318	0.0482

Continued...

Proposed Koolewong Marina Development - Aquatic Ecology Assessment

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Appendix 8, continued

Copper - comparison of sites

Groups	t	P(perm)	P(MC)
S1, S2	0.11225	1	0.913
S1, S3	11.513	0.3308	0.0072
S1, S4	3.2427	0.3342	0.0906
S1, S5	16.073	0.3314	0.0054
S1, S7	1.326	0.3302	0.318
S2, S3	5.8138	0.3328	0.0262
S2, S4	2.6811	0.3352	0.1098
S2, S5	5.0964	0.341	0.0404
S2, S7	1.1818	0.6734	0.3558
S3, S4	1.0541	0.6652	0.4056
S3, S5	2.5298	0.331	0.1298
S3, S7	1.4667	0.34	0.277
S4, S5	0.22086	1	0.853
S4, S7	0.66093	0.669	0.5796
S5, S7	0.92621	1	0.4748

Mercury - comparison of sites

Groups	t	P(perm)	P(MC)
S1, S2	2.75	0.341	0.1056
S1, S3	9.6667	0.3298	0.0108
S1, S4	15	0.3368	0.0058
S1, S5	15	0.3314	0.004
S1, S7	13	0.3246	0.0064
S2, S3	0.81929	0.6652	0.499
S2, S4	0.97014	0.6696	0.4388
S2, S5	0.97014	0.6706	0.4364
S2, S7	1.1163	0.6724	0.3826
S3, S4	0.27735	1	0.8108
S3, S5	0.27735	1	0.8024
S3, S7	5.0596	0.3326	0.0368
S4, S5	0	1	1
S4, S7	7.6026	0.3328	0.018
S5, S7	7.6026	0.3392	0.0148

Nickel

Main effect non-significant

Continued...

Proposed Koolewong Marina Development - Aquatic Ecology Assessment

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Appendix 8, continued

Lead - comparison of sites

Groups	t	P(perm)	P(MC)
S1, S2	1.0943	0.669	0.399
S1, S3	20.444	0.3388	0.0034
S1, S4	12.19	0.3356	0.0062
S1, S5	16	0.332	0.0036
S1, S7	0.66896	0.6678	0.5654
S2, S3	8	0.334	0.017
S2, S4	6.261	0.3386	0.0252
S2, S5	6	0.3356	0.0272
S2, S7	0.67082	0.6776	0.5738
S3, S4	2	0.3292	0.1786
S3, S5	Denominator is 0		
S3, S7	17.5	0.3388	0.003
S4, S5	2	0.333	0.1894
S4, S7	10.96	0.3346	0.009
S5, S7	13.5	0.3322	0.0052

Zinc - comparison of sites

Groups	t	P(perm)	P(MC)
S1, S2	0.47891	1	0.6724
S1, S3	15.949	0.3264	0.0026
S1, S4	4.7722	0.3244	0.042
S1, S5	12.519	0.3324	0.0066
S1, S7	1.1915	0.3322	0.3542
S2, S3	8.7654	0.3236	0.0152
S2, S4	4.3267	0.332	0.0508
S2, S5	6.9765	0.3228	0.0178
S2, S7	1.2999	0.671	0.3292
S3, S4	1.2649	0.6612	0.3322
S3, S5	2.8284	0.3324	0.1072
S3, S7	2.4711	0.3322	0.1302
S4, S5	0	1	1
S4, S7	1.4749	0.3346	0.2814
S5, S7	1.6866	0.337	0.2344

Continued...

Proposed Koolewong Marina Development - Aquatic Ecology Assessment

Prepared for ADW Johnson

Appendix 8, continued

Total Organic Carbon - comparison of sites

Groups	t	P(perm)	P(MC)
S1, S2	1.5856	0.3412	0.2474
S1, S3	9.4031	0.3376	0.0122
S1, S4	6.6157	0.3268	0.0262
S1, S5	8.2531	0.3376	0.0112
S1, S7	0.72349	1	0.531
S2, S3	9.3254	0.3368	0.0084
S2, S4	6.292	0.3252	0.0228
S2, S5	8.0919	0.3256	0.0138
S2, S7	0.39291	1	0.729
S3, S4	0.55407	0.6602	0.6398
S3, S5	1.0328	0.6642	0.4082
S3, S7	3.1576	0.331	0.098
S4, S5	0.3058	0.679	0.7908
S4, S7	2.6683	0.3426	0.1162
S5, S7	2.6351	0.3366	0.1148