Report to:
Northeast Business Park Pty Ltd

Redevelopment of Land at Caboolture: Aquatic Ecology Investigations for the Proposed Northeast Business Park

November 2007

The Ecology Lab Pty Ltd
Marine and Freshwater Studies

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Report Prepared for:

Northeast Business Park Pty Ltd
Post Office Box 1001
Spring Hill, Qld, 4004

Report Prepared by:

The Ecology Lab Pty Ltd
4 Green Street
Brookvale, NSW, 2100
Phone: (02) 9907 4440

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GLOSSARY & ACRONYMS

(Note: Definition of some terms obtained from the *Oxford Dictionary of Ecology* (2004) and the *Cambridge Dictionary of Statistics* (1998))

$\delta^{15}N$: Ratio of nitrogen isotopes used as an indicator sewage in the water.

ANOSIM: Analysis of Similarities. A permutation test based of similarity measures to determine variability (dissimilarities) among a sample of assemblages.

ANOVA: A statistical test that seeks to separate the variance attributable to one cause (or pattern) from the variance attributable to others. In this report ANOVA was used to determine the likelihood that populations of fish or invertebrates, or specific water/sediment quality indicators varied among sites or times of sampling.

Assemblage: A group of organisms present in a sample (or samples) collected from a similar habitat. The assemblage does not imply any functional relationships.

Benthic Macroinvertebrate: Invertebrate animals living on or in the sediment. By definition, macroinvertebrates are retained on a sieve of 1 mm mesh size.

Benthos: Collective term for benthic macroinvertebrates.

Biota: Collective term for plants and animals.

Capital dredging: Initial dredging of the navigational channel in the lower reaches of the Caboolture River.

CMD: Coastal Management District. The CMD includes lands up to the highest tide limit plus a buffer zone.

CAB: Coastal algal bloom. An outbreak of growth of algae, particularly the blue green alga *Lyngbya majuscula*.

Decapod: Evolutionarily advanced class of crustaceans. In this study, used as the collective term for shrimps, prawns and crabs, many of which are captured commercially or recreationally.

EHI: Ecosystem Health Index. An index developed by the Southeast Queensland Regional Water Quality Management Strategy to grade ecosystem health for a selection of water bodies in South East Queensland. EHI values are summarised as a series of annual report cards for selected areas, including the estuary of the Caboolture River.

EIS: Environmental Impact Statement. Formal Document which describes: 1) the proposed development, 2) the existing environment where the development would occur in time and space, 3) justification of the development, 4) possible alternatives, 5) the predicted impacts of the development, and 6) environmental management, including mitigation and monitoring. An EIS is usually accompanied by reports from specialists into a variety of technical matters. This report is the specialist report on aquatic ecology accompanying the EIS.

EPBC: *The Environment Protection and Biological Conservation Act* 1999. Commonwealth legislation which a proposal sets out requirements for assessing the effects of a proposal in terms of the Commonwealth's responsibilities.

ERA: Environmentally Relevant Activity. Formal recognition and regulation of many activities associated with the operation of the proposed project.

ESD: Ecologically Sustainable Development. Series of principles by which economic development should be progressed.

FHA (incl. FHA-013): Fish Habitat Area. Areas designated as fish habitat under Queensland State Legislation. FHA-013 is the area that covers Deception Bay and extending through tidal waters in the Caboolture River. It excludes designated navigational channels.

Invertebrate: terms for animals lacking a backbone (contrasts vertebrates including fish, amphibians, reptiles, birds and mammals).

Maintenance dredging: Ongoing dredging that would be required in the navigational channel of the Caboolture River periodically following initial deepening by capital dredging.

Marine Mammal: Comprises whales, dolphins, dugong/manatee, seals/sea lions/ walruses, etc. In this study applied to dolphins, dugong and whales.

Marine Plants (algae, mangroves, saltmarshes, seagrasses): Plants that live in estuaries, coastal and oceanic habitats. Algae include "seaweeds" and planktonic forms, here including the blue green alga *Lyngbya majuscula*. Mangroves, saltmarshes and seagrasses are vascular plants adapted to living emersed or partially emersed in salt water.

Marine Reptile: Comprises marine snakes, marine lizards (e.g. Galapagos iguana) and marine turtles. In this report refers exclusively to marine turtles.

MDS: Multidimensional Scaling. Graphical procedure used to depict the relationship of assemblages based on their similarities to one another.

Multivariate: Collective term for statistical analysis of assemblages

NEBP: Northeast Business Park, which is the development considered in this report.

Project site: Site where the NEBP would be built and operated.

Propagule: Dispersive part of an organism (e.g. seed, egg, planktonic larva).

SIMPER: Multivariate procedure used to determine which species or families of organisms contribute most to differences between sites or times of sampling.

Site Based Management Plan (SBMP): Plan developed for operational procedures within various part of the proposed NEBP project site. Includes a specific SBMP for the proposed marina precinct.

SNK: Student Newman Keuls Test. A multiple comparison statistical test used to differentiate treatment means (e.g. specific times or places). Applied following ANOVA only if the ANOVA shows that the treatment is statistically significant.

ToR: Terms of Reference specified by the Queensland Government Coordinator General in respect of the proposed NEBP development.

Univariate: Collective term for statistical analysis of populations or water quality indices.

Water Quality: Collective term for the relative health of a water body, usually based on a set of water quality indicators, such as dissolved oxygen, pH, turbidity and concentrations of chemicals such as heavy metals, nutrients or pesticides.

Wetland: Waterlogged land. In this report applies to estuarine wetlands that are lands containing marine plants (here usually mangroves and saltmarshes) and inundated by tidal waters.

WWTP: Waste Water Treatment Plant. A locality to which sewage is pumped and then treated to varying standards. In this study, WWTP's currently occur at South Caboolture and East Burpengary.

EXECUTIVE SUMMARY

INTRODUCTION

Background and Aims

Northeast Business Park Pty Ltd (NEBP) has acquired an area of land ("the project site") which is bounded by a section in the middle reaches of the estuary of the Caboolture River. The project site has been subject to a variety of land uses and NEBP proposes to develop the site as a large integrated development comprising a world-class business park complemented by a marine industry precinct including a marina that would ultimately contain up to 911 wet berths, up to 500 dry berths, associated residential and recreational areas including a golf course, sporting and recreational centres and an environmental centre. The development proposes to undertake significant riparian zone rehabilitation of a degraded site involving extensive buffer areas containing terrestrial, wetland and aquatic habitats. The development itself would utilise less than half the total area of the site. The Ecology Lab Pty Ltd was engaged by NEBP to advise on the potential impacts of the proposed development on aquatic ecology and on ways in which any negative impacts could be removed or mitigated. In addition, The Ecology Lab was also asked to provide advice on how aquatic habitats could be restored.

This document is a preliminary report prepared during the investigations of aquatic ecology for the proposed development. Much of the background information and data presented in this report will be incorporated into the main report on aquatic ecology, to be finalised once all investigations of aquatic ecology have been completed.

At this stage of the investigation of aquatic ecology, there are no constraints that have been identified to the proposed development that could not be mitigated by appropriate construction procedures or by management action.

Government Requirements

Government requirements for the environmental assessment process have been developed as Terms of Reference (ToR) by the Co-ordinator General with input from the proponent, government departments and responses from the community and local groups to exhibition of draft ToR. The Ecology Lab has been provided with the ToR and this specialist report has been prepared to address specific issues related to aquatic ecology that have been specified in the ToR.

Key ToR that are relevant to aquatic ecology are summarised in Table ES1, which also identifies those sections within the report that address those ToR.

EXISTING ENVIRONMENTAL INFORMATION

Geographical Setting

The project site comprises four adjoining parcels of land totalling 769 ha. The site is 7 km from Caboolture and its eastern boundary is about 4.8 km from the mouth of the Caboolture River. The site is largely vacant and was used previously for low to medium agricultural purposes (pine plantation). The site has been largely cleared and now comprises little terrestrial vegetation, although mangroves are present along the sides of the Caboolture

River. The site is believed to be largely free of acid sulphate soils, although other specialists will address this issue in detail as part of the site assessment.

The northern area of the project site along the river falls within an Ecological Corridor Designation, hence any development plan should provide for connectivity of habitat along the river. The southwest corner of the site has been identified as State Nature Conservation Area. Deception Bay and the lower reaches of the Caboolture River are within a Habitat Protection zone of the Moreton Bay Marine Park and part of the Moreton Bay RAMSAR site. The park boundary ends at the north eastern boundary of the of project site. The Caboolture River frontage and tidal waters of the project site are also part of the declared Fish Habitat Area under the *Fisheries Act* 1994.

A weir used as a source of freshwater has been constructed across the Caboolture River 19 km upstream of the river mouth. The weir forms a barrier to saltwater intrusion from Moreton Bay and hence forms the upper limit of the estuary of the river. It reduces the amount of estuarine habitat present compared to the original river, it affects water quality, particularly salinity, and it impedes the movement of aquatic organisms within the river, many of which migrate between saltwater and freshwater. Relatively few creeks flow into the Caboolture River downstream of the weir. Sheep Station Creek flows into the river from the south just upstream of the Caboolture wastewater treatment plant (WWTP). Goong Creek flows into the river from the north and on the opposite side of the river to the NEBP property. Raff Creek is a small watercourse that passes across the NEBP property and into the Caboolture River. Upstream of the study site, Raff Creek flows through residential areas and has been altered by the excavation of ponds. Thus there is potential for this creek to contain diminished water quality due to influences upstream of the study site. The largest tributary of the Caboolture River is King John Creek, which flows into the Caboolture River from the north, about 3 km upstream of the river mouth.

Water Quality

Water quality within south east Queensland has received extensive consideration by government as a means of assessing the ecological health of Moreton Bay and the freshwater and estuarine components of rivers within the region. The South East Queensland Regional Water Quality Management Strategy ("the Strategy") is a partnership between state, local and commonwealth governments and academic institutions that identifies management objectives and provides a framework for integrated and co-operative management actions to protect the waterways of south east Queensland.

One initiative of the Strategy is the implementation of an Ecosystem Health Monitoring Program (EHMP). This program includes monitoring to assess the effectiveness of management actions within the Strategy and provides an audit mechanism for management action. The Caboolture River consistently has graded poor to fair and this can be attributed at least in part to the discharge of treated effluent from the Caboolture WWTP. A key issue for the design and management of the NEBP will be to evaluate the potential for cumulative effects with existing uses, including the WWTP discharge and, where possible, to assist in initiatives to improve the ecological health of the estuary. Water quality investigations being undertaken as part of the environmental impact assessment for the project (and to be documented in the main report) will provide input into this process.

Concerns about water quality in waterways of South East Queensland have prompted innovative approaches to managing pollutant loads. One such initiative has been the investigation of potential for trading schemes for licenced discharges, including nutrient minimisation and offset schemes. NEBP has the potential to have significant input into such schemes, for example by ensuring best practice in stormwater management and providing open areas for effluent re-use, which could be used to offset nutrient loads from the South Caboolture WWTP and hence improve the quality of habitat within the river.

Flora, Fauna & Aquatic Conservation

The waterways of south east Queensland contain a large variety of aquatic habitats, with key habitats in and adjacent to estuaries being mangroves, saltmarshes, seagrasses and unvegetated flats and channel beds. In addition, artificial structures, including moorings and jetty piles, provide habitats for aquatic flora and fauna. There are approximately 15,000 ha of mangroves in Moreton Bay, but no detailed estimate of the area of mangroves fringing the Caboolture River has been identified. In 1987 it was reported that there were 3,000 ha of saltmarshes in the bay, but no estimates of change have been identified since that time. Saltmarshes often occur landward of mangrove forests and are inundated only by spring tides. Saltmarshes in subtropical Queensland are completely submerged for only about 1% of the time, but with a strong seasonal component. Thus, saltmarshes are virtually never completely inundated by tides in spring and autumn, but are inundated for 3% of the time during winter and summer. It was estimated that some 25,000 ha of seagrasses occurred in Moreton Bay in 1998. Over the last 30 years there have been extensive changes in seagrass cover, particularly in the northern sections of Moreton Bay (e.g. Deception Bay).

The distribution of aquatic habitats, particularly mangroves, saltmarshes and potentially seagrasses, has significant implications for the proposed NEBP. These habitats are important for a variety of organisms, including fish and invertebrates of commercial and recreational value, shorebirds and, specifically in the case of seagrasses, for dugongs. They are given a high conservation value and they are also susceptible to a number of anthropogenic activities. There are opportunities for the design and management of the NEBP to maintain and in some cases restore and improve aquatic habitats in the Caboolture River.

A large fish habitat area has been declared in Deception Bay and extending into Burpengary Creek and into the Caboolture River as far upstream as the weir (FHA No. 013). The fish habitat area also includes some of the tidal creeks of the river, including Sheep Station Creek, Goong Creek and King John Creek. In relation to the NEBP, the fish habitat area extends along the study site’s frontage with the river and a short way into Raff Creek. This creek is included in the buffer set aside in the design of the development. It should be noted that, under the Fisheries Regulations a fish habitat area does not include the area of a channel marked by aids to navigation. The Caboolture River has a defined channel marked with navigation aids; hence there are some exclusions to the fish habitat area within the river.

An important component of the development of the NEBP is the consideration and management of issues related to threatened species. The *Nature Conservation Act 1992* (*NC Act*) provides for the protection of all plants and animals native to Queensland and the ecosystems in which they live and lists species, populations and ecological communities which have been classified as threatened in Queensland. This Act integrates the consideration of threatened species into the planning process for proposed developments. The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) commenced in July 2000 and is administered by the Department of Environment and Water Resources (DEWR).

Three species of fish, three species of marine mammals, five species of marine reptiles and ten species of birds in the endangered, vulnerable, rare or migratory schedules of the *NC Act* or *EPBC Act* were identified as relevant to the proposal. One Ramsar site (Moreton Bay) as listed under the *EPBC Act* was identified. Ramsar and bird issues are being addressed in detail by other specialists engaged on this project.

FIELD INVESTIGATIONS

The project site and surrounding areas have been studied by staff from The Ecology Lab since December 2004. Ongoing and more detailed studies were undertaken from December 2005 to August 2006, with additional supplementary works planned for March 2007 in relation to requirements for capital dredging of the lower reaches of the Caboolture River.

Investigations to date have identified the following features in relation to aquatic ecology:

- The project site comprises several areas of aquatic habitat, the most significant appearing to be Raff Creek and areas of mangroves and saltmarshes fringing the site boundary and Caboolture River. The tidal portion of Raff Creek habitat appears to be included within the Deception Bay Fish Habitat Area and it would be protected within a buffer as part of the proposed development. Upstream of the tidal influence, this creek forms a drainage line. Further upstream and beyond the southern boundary of the study site, a series of artificial, freshwater ponds has been excavated amid residential properties.
- The proposed entrance to the marina is in a section of the river subject to some erosion and with few aquatic plants. Several small, mangrove-lined channels occur to the east of the proposed marina entrance. Three species of mangroves have been identified on the site – grey mangroves (*Avicennia marina*), milky mangroves and river mangroves (*Aegiceras corniculatum*). The channel closest to the proposed entrance contains little water and, at this stage, is considered to be of limited value as aquatic habitat.
- The weir on the Caboolture River forms a major barrier to fish passage (despite the presence of a small fishway) and has significant effects on the distribution of aquatic plants and on water chemistry.
- Whilst the Caboolture River retains significant features, there has been obvious alteration of the river by human activities in addition to the weir. Downstream of the study site is Monty's marina and slipway. This contains moorings within the main river channel and along the northern boundary of the river; it also has a large hardstand area and slipway running directly into the river. Further upstream, near the entrance to Goong Creek, there is a small residential area with several large vessels moored on the side of the river channel. In addition, there are small foreshore works, bank stabilisation and private slipways. Finally, there are two Wastewater Treatment Plants, one discharging into the Caboolture River just downstream of the weir and one near the entrance to the river, discharging into Burpengary Creek. These WWTP's have been identified as problematic in previous studies (see above).
- Parts of the Caboolture River are in areas prone to shoreline erosion, particularly where natural vegetation has been cleared to the edge of the river channel. Mangroves have provided some stabilisation of banks, particularly by the growth of

pneumatophores (peg roots) which hold the sediment together. Potential processes causing erosion identified to date include:

- land clearing and cattle grazing,
- possible changes to flow and sediment transport associated with construction of the weir, and
- vessel traffic on the river.

- At the project site there is evidence of degradation due to unauthorised access onto the property. This includes debris such as vehicles dumped on the shoreline and even in the river, and erosion of dirt tracks exacerbated by 4WD vehicles. Significant opportunities exist to improve the shoreline of the property boundary by implementing appropriate management practices.
- Measurement of water quality within the Caboolture River provided strong support for the findings of other assessments, namely that water quality is poor. This was evidenced by supersaturation of oxygen in surface waters and depletion of oxygen at the bottom and by high levels of turbidity. High levels of nutrients have also been detected in river waters in December 2005 and January 2006. Levels of metals in the water indicate elevated concentrations of copper and perhaps iron and aluminium.
- Sampling of the chemical characteristics of sediments revealed that upstream of the confluence of the Caboolture River with the Bruce Highway there is comparatively little sediment in the river channel. This may be an effect of the weir, which could interfere with sediment transport into the estuary from the catchment. Concentrations of metals were low compared to ANZECC (2000) sediment quality guidelines, although nickel and copper were slightly greater than the ANZECC Effects-range Low guidelines in some samples. Whilst no ANZECC guideline exists for aluminium and iron, concentrations were often high, but very variable among samples, both within the river channel and in tidal channels on the project site.
- Surveys of benthic invertebrates indicated a relatively low-diversity assemblage occurring both in the river channel (sub-tidal) and on river banks not colonised by mangroves. Fish communities in tidal creeks in and around the project site were dominated numerically by mosquito fish, an introduced species. Sampling did, however, yield a number of native species, including ones of economic interest. Sampling in the river channel yielded more species of fish, but the sampling method was hampered by strong currents and limited areas available for sampling.
- Further work on invertebrates and fish in the navigation channel proposed for capital dredging and on adjacent intertidal flats indicated large spatial and temporal variability in invertebrate assemblages. Assemblages of benthic invertebrates were relatively distinct between the navigation channel and flats, although fish assemblages were quite similar at the two habitats, suggesting that fish may range from the channel over the flats at mid to high tide. Three channel sites that were common to sampling of invertebrates in April 2006 and March 2007 showed distinctive assemblages, indicating temporal variability.

SYNTHESIS OF AQUATIC ENVIRONMENTAL VALUES

Table ES2 summarises key environmental values at the project site and in the Caboolture River. Studies that have been done in relation to ecological health and as part of the current proposal identify ecological problems with nutrients in the Caboolture River. The key issues for the proposed NEBP project are to work within this framework to unsure the use of best practice, to maintain tidal and flooding processes to allow flushing of river waters (and maintain connectivity within the river for biota) and to implement careful management supported by monitoring of the waters of the marina basin. On the other hand, there are significant opportunities for contributing to an improvement of the river by the re-use of treated wastewater on the project site from existing discharges.

There is a range of aquatic habitats in the Caboolture River with a subset of these habitats on the project site (Table ES2). There are no unique or particularly extensive habitats on the project site; and all of the aquatic habitats on the site occur elsewhere in the Caboolture River.

A range of conservation issues was considered with respect to aquatic ecology. In general, marine mammals are not likely to be common in the area, although several species of dolphins may occur in the river and Deception Bay. As far as is known, threatened species of fish do not occur in the estuary of the Caboolture River, although there is habitat suitable for the honey blue-eye. The Deception Bay Fish Habitat Area extends from the bay up the Caboolture River to the end of the estuary at the weir. The FHA also extends into the tidal reaches of creeks, including Raff Creek, within the project site. The FHA area is assessed as being of only low to moderate value because of the occurrence of Lyngbya blooms and lack of management leading to destruction of wetland habitat by 4WD vehicles, dumping of cars and rubbish, etc. The proposed development provides an opportunity for enhanced local participation in, and assistance with, management of the FHA. The coastal management District (CMD) includes lands up to the high tide level and beyond to the width of a buffer. In most cases, the FHA and CMD are preserved under the proposed development, the exception being in and around the proposed marina basin.

The Moreton Bay Marine Park also extends into the Caboolture River and encompasses part of the river channel fronting the project site. The park is assessed as having very high environmental value, given the large human population in the region and increasing usage of the resources and amenity of Moreton Bay.

The study has identified two pest species within the estuary of the Caboolture River and Deception Bay (Table ES2). Construction and management of the proposed development both have a role to play in ensuring that the effects of these species are not increased, and possibly in helping to control them.

Both recreational and commercial fishing occur in the estuary of the Caboolture River. Previously, shore-based anglers gained illegal access to the NEBP site. People also gained access to the site to dump rubbish, including cars. Under the proposed development there is an opportunity to provide managed access which would allow shore-based fishing and prevent the vandalism observed in the past. The estuary itself is considered to have a high environmental value for recreational fishing (Table ES2) due to the availability of access (and potential for improved access), moderate diversity of target species and large human population in the region.

ASSESSMENT OF IMPACTS & ESD

The EIS places a great emphasis on the design of the proposal as being ecologically sustainable. As identified in the EIS, there are risks associated with the construction activities. In the context of aquatic ecology, these risks are related to management of water, acid soils and dredging operations. Each of these is considered in a precautionary context, with commitments from the proponents for monitoring and management. Operationally, various processes and procedures (e.g. Site Based Management Plans) are identified to ensure consideration of the aquatic environment. In particular, monitoring of a range of potential contaminants of concern would be implemented as part of the SBMP for the marina.

Importantly, the staging of availability of marina berths provides an orderly means of assessing changes in the aquatic environment of the marina basin. This can be used to set and measure performance indicators of ecological health.

In addition, sewage pumped to South Caboolture WWTP would be treated to a high standard and re-used: this would benefit not only the proposed development, but would assist in addressing existing problems with the ecological health of the Caboolture River. Moreover, it is understood that the increased sewage flows to East Burpengary WWTP would trigger fast-tracking of the upgrading of treatment and disposal there. This may help to alleviate problems with coastal algal blooms (specifically Lyngbya) in Deception Bay.

Two other issues associated with the proposed development warrant consideration of a precautionary approach:

1. The construction of two of the eight flood mitigation embankments which extend into the coastal management district. If these significantly affect the flow of flood and tidal waters within wetlands, then they may cause a loss of wetland habitat and diminish, on a small scale, the value of the Fish Habitat Area. Access to the embankment sites during construction may also impact upon wetland habitat. A precautionary approach suggests that the siting of the embankments be done to minimise the loss of wetland habitat and to minimise any changes to normal water movement that could adversely affect to wetland.
2. Effects of capital and ongoing maintenance dredging on flats adjacent to the navigational channel in the lower reaches of the Caboolture River. The predicted replenishment of sediments in the navigational channel including a contribution from adjacent banks represents potential for impacts beyond the channel and hence within FHA-013. A precautionary approach suggests further modelling of siltation processes be done to identify exactly where and by how much the adjacent flats could be affected by ongoing dredging. This could then be used to define more precisely the dredging program.

In summary, the project has been designed to be consistent with principles of ESD and measures have been identified within the EIS to address sustainability during construction and operation. As may be expected in a project of this size, there are some additional measures that need more detailed consideration, including location of some flood mitigation embankments and effects of capital and maintenance dredging on adjacent flats in the lower estuary of the Caboolture River.

ENVIRONMENTAL MANAGEMENT

A precautionary approach to the proposed Northeast Business Park development at Caboolture requires the design and implementation of management plan for matters related to aquatic ecology and maintenance or improvement of aquatic environmental values. The following core components for this management are as follow:

1. Design of safeguards for various activities and to cover unforeseen events, such as spillages.
2. Development of key performance indicators (PIs) against which safeguards can be measured.
3. Development of audits or monitoring programs to measure the PIs.
4. Feedback mechanisms to ensure that corrective action is initiated appropriately and within an appropriate time frame.

Numerous safeguards have already been developed as part of the EIS for the project. In terms of performance indicators, there are some PIs for components of water quality are readily available as water quality guidelines. The Healthy Waterways Strategy 2007 – 2012 provides water quality objectives to protect the aquatic ecosystem specific to the Caboolture River. These apply to the lower, mid- and upper estuary and include nutrients, dissolved oxygen, turbidity, chlorophyll-a, Secchi depth, suspended solids and pH. Some of the other typical indicators, such as contaminants of concern (e.g. some metals, oil and grease, pesticides) can be based in the ANZECC (2000) water quality guidelines.

PIs for biodiversity would be developed around comparisons of field data to background conditions and, where available, to control locations, that is, an "ecological baseline". Once the extent of natural variability is defined PIs that under-perform or exceed the ecological baseline would be evaluated against a precautionary approach and the consequences of management action or inaction determined. Given the lead time available prior to commencement of works, it is highly advisable that an ecological baseline of data is acquired as soon as practicable.

Current best practice in ecological monitoring usually entails a "BACI" (Before-After-Control-Impact) approach. This requires replicated quantitative sampling on multiple occasions before and after (and, if appropriate during) the period(s) of environmental disturbance at the site of disturbance and at multiple control sites.

Feedback mechanisms are essential to ensure that management responds to impacts to the aquatic environment that have been detected either from monitoring of perhaps following mishaps (e.g. a spillage). Feedback should be developed well in advance and include allocation of specific tasks to specific job roles.

These components of environmental management are applicable to both the construction and operational stages of the project.

Table ES1: Terms of Reference Addressed in this Report

Note: Section numbers refer to address within this report; EIS refers to the main document of the EIS; SP refers to various specialist reports appended to the EIS (e.g. Acid Soils Management Plan); NES refers to the specialist report on Matters of National Environmental Significance prepared by Cardno and The Ecology Lab and appended to the EIS.

	Terms of Reference	Section(s)
1.	**Description of the project. (ToR 3)** This includes information relevant to the description of the project, such as:	
	a. Site location in relation to aquatic protected areas (Ramsar, Fish Habitat Area 013 and Moreton Bay Marine Park).	2.1, 2.3, Fig 1
	b. Location and extent of the marina precinct.	2.1, 5.1, Fig 1
	c. Capital works necessary for upgrading the navigability of the Caboolture River.	5.2.2
	d. Extent of vegetation areas and buffer zones in and surrounding the project site	2.2.4, 3.1.2, 3.2.1, Figs 9 & 10
	e. Landscaping and rehabilitation proposals.	5.1.1, 5.3.5
	f. Location and scope of open space areas including public facilities, public and private open space, protected areas and stormwater management areas.	5.3.5
	g. Details of sustainability initiatives proposed.	4.0, 5.1, 5.4, 5.5
2.	**Ecologically Sustainable Development (ESD) (ToR 3.1)** – to be considered using standard criteria such as defined by the *Environmental Protection Act (Qld).*	5.4
3.	**Construction Issues (ToR 3.4)**	
	a. Project Site, with particular emphasis on aquatic habitats and frontage along the Caboolture River.	5.1.1, 5.2, 5.3, 5.5.1
	b. Capital dredging of the navigation channel.	5.1.2, 5.2.2, 5.5.5.4
4.	**Operational issues (ToR 3.5)**	
	a. Activities within the marina precinct.	5.3.4
	b. Vessel movements within the Caboolture River.	2.2.1, 5.3.4, 5.5.4
	c. Maintenance dredging in the marina basin and navigation channel of the Caboolture River, including methods of minimising dredging plumes and potential release of contaminants on water quality.	5.1.3, 5.3.4, 5.5.5.4, 6.3
5.	**Infrastructure requirements (ToR 3.7)**, including the following matters that are potentially relevant to aquatic ecology:	

	a. Transport issues, including proposed waterway crossings.	5.3.1
	b. Water supply and storage, particularly how the possible recycling of water from Council's South Caboolture Sewerage Treatment Plant could benefit the aquatic ecology of the Caboolture River.	5.3.2, 5.4
	c. Stormwater drainage, including the potential concentration of drainage flows into water courses in terms of hydrological and ecological implications for aquatic and fisheries resources.	5.3.2
	d. Sewerage, in relation to the potential impact on the nutrient loads being discharged to the Caboolture River and Moreton Bay, as a result of the increase in treated effluent resulting from the proposal.	5.3.2, 5.3.3, 5.5.2, 6.3
6.	**Waste management (ToR 3.8),** including issues associated with groundwater from excavations, rainfall onto disturbed, surfaces and seepages.	5.2, 5.3.2
7.	**Environmental values and management of impacts (ToR 4).** The ToR require a description of existing environmental values in the area that could be affected, with values as defined in the *Environmental Protection Act 1994*, Environmental Protection Policies and other documents such as ANZECC (2000) and the South East Regional Water Quality Management strategy. Values are to be considered in terms of potential adverse and beneficial impacts; potential cumulative impacts, environmental protection objectives and standards, and measurable indicators (evaluated by monitoring and environmental audit) to be achieved; and feasible alternative strategies for managing impacts. Specific matters identified in terms of aquatic ecology include the following:	4.0, Table 43 (also Table ES2)
	a. Landform, including:	
	i. topography, geomorphology and bathymetry.	2.2.1, 4.0, 5.5.1, 5.5.5.4
	ii. Soils, specifically in relation to Acid Sulphate Soils.	1.3, 2.2.3.2, 4.0, 5.2,
	iii. Sensitive environmental areas, particularly in relation to aquatic reserves, fish habitat areas, sites covered treaties or agreements, etc.	2.3, 4.0, 5.5.5, 6.0
	iv. Potential impacts and mitigative measures, including land contamination and soil erosion.	4.0, 5.5, 6.0
	b. Water resources, including:	
	i. Surface waterways in terms of water quality and quantity (on a seasonal and event-based scale), existing surface drainage patterns and flows in major streams and wetlands. A description is required, including photographic evidence, of the geomorphic condition of watercourses likely to be affected by disturbance or stream diversion.	2.2.3, 3.2.2, 4.0, 5.2, 5.3, 5.4, 5.5
	ii. Groundwater	EIS
	iii. Potential impacts and mitigation measures, including the development of a water management strategy which considers	5.2, 5.3, 5.4, 5.5.2, 6.2, 6.3

protection of the integrity of the marine environment, maintenance of sufficient quantity and quality of surface waters to protect existing beneficial downstream uses of those waters (including in-stream biota and the littoral zone).	
iv. Preparation of a risk assessment for uncontrolled emissions to water due to system or catastrophic failure, implications of such emissions for human health and natural ecosystems and provision of strategies to prevent, minimise and contain impacts.	4.0, 5.5.2, Table 43; EIS
c. Coastal environment:	
i. Provide baseline water quality data for the Caboolture River and relevant tributaries downstream of the tidal limit (i.e. Caboolture Weir), including heavy metals, acidity, turbidity and oil in water.	2.2.3, 3.2.2
ii. Discuss the interaction of freshwater flows with marine waters and its significance to marine flora and fauna adjacent to the proposal area.	3.2.1.3, 4.0, 5.5.2, Plate 4
iii. Describe coastal resources in terms of values identified in the:	
• *Environment Protection (Water) policy.*	EIS
• *The State Coastal Management Plan 2001.*	EIS
• *The South East Queensland Regional Coastal Management Plan 2006.*	EIS
iv. Describe coastal processes in relation to:	
• Physical and chemical characteristics of sediments in the littoral and marine zones adjacent to the project site.	SP; 3.2.3, 3.2.6
• Physical & coastal processes such as currents, tides, storm surges, freshwater flows, bathymetry, sedimentation and erosion, and assimilation and transport of pollutants entering marine waters from the project site.	SP; 5.1, 5.2, 5.5.2
• Marine sediments and sediment quality in the area likely to be disturbed by dredging or vessel movements including contamination (e.g. heavy metals, nutrients, pesticides), presence of fines &/or indurated layers and acid sulphate potential. Present this information as a map of sediment types based on their physical and chemical properties, with depth profiles.	SP; 2.2.3, 3.2.3, 4.0
• Environmental values of the coastal resources of the area potentially affected by the project in terms of the physical integrity and morphology of landforms created or modified by coastal processes.	4.0; EIS
v. Potential impacts and mitigation measures, including: • Consistency of the project with the *State Coastal*	EIS

Management Plan 2001 and *The South East Queensland Regional Coastal Management Plan 2006.*	
• Potential impacts on tidal hydrodynamics in the Caboolture River, Pummicestone Passage and Deception Bay.	SP; 5.5.2
• Potential impacts on bank erosion and adjacent waterways.	SP; 5.3.4, 5.5.1,
• Potential impacts of proposed capital and maintenance dredging, including access to dredge material disposal areas.	5.2.2, 5.3.6, 5.5.5.4
• Water quality objectives and practical measures for protecting or enhancing coastal environmental values, including achievement of standards and monitoring, auditing & management of objectives.	EIS; 6.0
• Potential threats to water quality and sediment quality in the Caboolture River associated with construction and operation, including: method and timing of excavation of the marina basin and spoil disposal; potential accidental discharges of contaminants during operation of the marina precinct; release of contaminants from marine structures and vessels, including antifouling coatings; and stormwater runoff from developed areas.	EIS; 5.1.1, 5.2.1, 5.3.2, 5.3.4
• The role of buffer zones in sustaining fisheries resources through maintaining connectivity between coastal and riparian vegetation and estuarine and freshwater reaches of catchments.	4.0, 5.1.1, 5.2.1.1, 5.3.5, 5.4
• The potential impact of the proposed project on blooms of the hazardous cyanobacteria *Lyngbya majuscula* in Deception bay and the Caboolture River (include reference to policy 2.4.7 of *The South East Queensland Regional Coastal Management Plan 2006*).	2.2, 3.3, 5.2.1.3, 5.3.2, 5.4, 6.0
d. *Noise and vibration*: Assessments in relation to this matter should include environmental impacts on terrestrial and marine animals and avifauna, particularly migratory species.	5.5.5.4
e. *Nature conservation*:	
i. Environmental values of nature conservation are to be described in terms of:	
• Integrity of ecological processes, including habitats or rare and threatened species.	4.0, 5.5
• Conservation of resources.	4.0, 5.5.5
• Biological diversity, including habitats of rare and threatened species.	2.3, 4.0, 5.5
• Integrity of landscapes and places including wilderness	5.1.1, 5.3.5, 5.5

and similar natural places. • Aquatic and terrestrial ecosystems, with particular emphasis for this specialist report on waterways, riparian zone, littoral zone and aquatic habitat corridors. Vegetation should be mapped and species listed, and assessed at a local, regional and state scale.	2.0, 3.1.2, 3.2.1, Figs 9 & 10, Plates 1, 2 & 3
ii. Coastal biodiversity values as mapped or described by the *State Coastal Management Plan 2001* &/or *The South East Queensland Regional Coastal Management Plan 2006* to be identified and an ecological survey and assessment of flora and fauna associated with these areas containing coastal biodiversity values undertaken (to 100 m from these areas).	2.0, 3.0, 4.0
iii. Identify issues relevant to sensitive areas which may have low resilience to environmental change (e.g. marine environment and wetlands, wildlife breeding areas).	3.2.1, 4.0, 5.1, 5.2, 5.3
iv. Assess the capacity of the environment to assimilate discharges/emissions and describe proximity of the project site to any biologically sensitive areas.	3.2.1, 4.0, 5.2.2, 5.3.6
v. Refer to State and Commonwealth endangered species legislation and proximity of the area to the Great Barrier Reef World Heritage Property.	NES; 2.3, 4.0, 5.5.5
vi. Describe the occurrence of any pest plants and animals relevant to this specialist report.	2.2.3.3, 3.2.5.1, 4.0, 5.3.3
vii. Identify key flora and fauna indicators for future monitoring. Where necessary, conduct surveys to reflect possible seasonal variation.	6.0
viii. In relation to aquatic ecology, the ToR identify the following tasks:	
• Conduct biota studies/surveys in and downstream of the project site if none have been done previously, noting patterns of distribution in the waterways and/or associated marine environments. Include the following:	3.0
o Fish species, mammals, reptiles, amphibians, crustaceans and (other) aquatic invertebrates occurring within the affected area and/or those in the associated marine environment.	3.2.4, 3.2.5, 3.2.6
o Identification of types and spatial distribution of economically important fish species, including their migratory requirements.	5.5.5.8
o The principal fishes and crustaceans occurring in and adjacent to the project site should be listed, their recreational, traditional and commercial fisheries interest identified and their present	SP; 3.2.5, 4.0

abundance and distribution assessed.	
o Any rare or threatened marine species, particularly dugong and its habitat.	2.3, 4.0, 5.5.5.6
o Define the nature and extent of existing marine features such as littoral and sub-littoral lands, waterways, affected tidal and sub-tidal lands, corals and marine vegetation such as salt couch, seagrass, mangroves within and adjacent to the project site.	3.2.1, Plates 1, 2, 3 & 6
o Aquatic plants (including algal species).	2.2.3.3, 2.2.4, 3.2.1, 4.0, 5.5.5.2
o Aquatic and benthic substratum.	3.2.1, 3.2.3, 3.2.6.1
o Habitat downstream of the proposal or potentially affected by it.	3.2.1
ix. Potential impacts and mitigation measures:	
• Address actions that require an authority under the *Marine Parks Act 1994*, *Nature Conservation Act 1992* and *EPBC Act* and/or would be assessable development for the purposes of the *Vegetation Management Act 1999*.	EIS; NES
• Discuss any likely direct and indirect environmental harm due to the project on flora and fauna in any particularly sensitive areas. Consider short term and long term effects of construction, operation and decommissioning of the project and identify if these effects are reversible or irreversible.	5.2, 5.3, 5.4, 5.5
• Describe strategies for protecting the Moreton Bay Marine Park, any rare or threatened species and consider obligations imposed by State or Commonwealth legislation or policy of international treaty obligations (emphasis to be given to benthic and intertidal communities, seagrass beds and mangroves).	4.0, 5.2, 5.3, 5.4, 5.5
• Discuss impacts due to - and mitigation of – alterations to:	
o Local surface and groundwater.	5.5.2; EIS
o Stream or tidal flows and sediment deposition due to dredging with specific reference to benthic environments, fish habitat and migratory bird species using the mouth of the Caboolture River.	EIS; SP; 5.2.2, 5.3.6, 5.5.2
• Identify provision of buffer zones and movement corridors.	5.5.1, 5.5.5.8

• Develop a Pest Management Plan where relevant for aquatic ecosystems and include as part of the overall Environmental Management Plan for the project.	EIS; 4.0, 5.3.3
• Areas regarded as sensitive with respect to flora and fauna and which should be identified, mapped, avoided or managed to minimise effects include:	
o Areas of nature conservation and interest declared in the Marine Parks (Moreton Bay) Zoning Plan 1997.	2. 3, 4.0
o Fish Habitat Areas as declared under the *Fisheries Act 1994.*	2.3, 4.0, Fig. 1
o Habitats of species listed under the *Nature Conservation Act 1992* &/or *EPBC Act* as presumed extinct, endangered, vulnerable or rare.	2.3; NES
o Regional ecosystems listed as "endangered" or "of concern" under state legislation &/or ecosystems listed under the *EPBC Act* as presumed extinct, endangered, vulnerable or rare.	SP; NES; EIS
o Good representative examples of remnant regional ecosystems which are poorly represented in protected areas.	SP; NES
o Sites listed under international treaties such as Ramsar or World Heritage.	NES
o Sites containing near threatened or bio-regionally significant species or essential, viable habitat for such species.	4.0; SP; NES
o Sites in, or adjacent to, areas containing important resting, feeding or breeding sites for migratory species of conservation concern listed under treaty.	NES; SP
o Sites adjacent to nesting beaches, feeding, resting or calving areas of species of special interest (e.g. marine turtles, cetaceans).	NES; 2.3, 5.5.5.6
o Sites containing common species which represent a distributional limit and are of scientific value.	NES; 4.0
o Sites containing high biodiversity that are of suitable size or with connectivity to corridors/protected areas to ensure survival in the longer term (e.g. natural habitat in good condition, such as wetlands; or degraded vegetation or other habitats that still supports high levels of biodiversity or is a corridor for maintaining high levels of biodiversity in the area.	4.0; 5.5.5.8
o A site containing other special ecological values	

(e.g. high habitat diversity, high area of endemism).	4.0
o Ecosystems providing important ecological functions, such as: wetlands of national, state and regional significance; coral reefs, riparian vegetation, important buffer to a protected area or important habitat corridor between areas.	2.2.4. 3.2.1, 4.0
o Areas that are proclaimed or are under consideration for proclamation under the *Nature Conservation Act 1992* and *Marine Parks Act 1982*.	2.3, 5.5.5.7
o Areas of major interest, or critical habitat declared under the *Nature Conservation Act 1992* or high conservation areas vulnerable to land degradation under the *Vegetation Management Act 1999*.	EIS
• Specific issues to be addressed associated with aquatic ecology include:	
o Assessment of the impact of the project on juvenile and adult aquatic species leading to a loss of productivity in fish, crustaceans, etc.	5.5.5.1
o Description of any loss of seagrasses in relation to the extent and regional significance of seagrass communities and associated impacts on fisheries, dugongs, marine turtles, etc.	5.5.5.2
o Discuss the impact of the creation of permanent deep water within the marina and likely colonisation of the marina and marine structures.	5.5.5.3
o Potential impacts associated with dredging and spoil disposal.	5.1.2, 5.1.3, 5.2.2, 5.3.6, 5.5.5.4
o Potential impacts associated with altered tidal conditions and degraded water quality.	SP; 5.2.1.2, 5.2.1.3, 5.2.2, 5.3.4, 5.3.6, 5.5.5.5
o Description of mitigation measures to reduce the impacts on turtles and dugong related to increased recreational and commercial use.	4.0, 5.3.4, 5.3.6, 5.5.5.6
o Assessment of impacts on Moreton Bay Marine Park and associated Ramsar wetlands through dredging activities and increased marine traffic and visitation.	5.5.5.7
o Potential impacts on movements of aquatic species or construction of any waterway barriers (permanent or temporary) and measures to	5.5.5.8

	avoid/offset/mitigate these impacts. • The proposed project should demonstrate consistency with policies of the State Coastal Management Plan &/or the South East Queensland Regional Coastal Management Plan under the topic heading: 2.8 Conserving Nature.	EIS
8.	**Environmental Management Plan (ToR 4).** The purpose of the EM Plan will be to set out how environmental values will be protected and enhanced as a result of the project. It should be capable of being viewed as a stand-alone document with the following general contents:	
	a. *Acceptable levels of environmental performance, including environmental objectives, performance standards and associated measurable indicators, performance monitoring and reporting.*	6.1
	b. *Impact prevention or mitigation actions.*	6.1, 6.2, 6.3
	c. *Corrective actions to rectify any deviation from performance standards.*	6.2, 6.2, 6.3

Table ES2. Summary and Analysis of Aquatic Environmental Values.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Water & Sediment Quality	Health of Caboolture River estuary	1) Extent of estuary truncated by weir; 2) Reduced riverine input; 3) Discharges from Municipal Waste Water Treatment Plants (WWTP's); 4) Bank erosion with potential increases in turbidity; 5) Other human activities (e.g. existing marina).	1) High levels of nutrients; 2) Potential erosion; 3) Ecological impacts of weir.	Low value due to 1) Poor health; 2) Limited connectivity with river upstream of weir; 3) bank erosion. Leads to high ecological cost.	1) Use best practice to ensure NEBP does not increase current nutrient problems; 2) Need to ensure development does not interfere with tidal and flooding processes; 3) Significant opportunities for re-use of treated waste water from WWTP's to improve water quality of the estuary; 4) Need to monitor & manage water quality in marina basin, including antifouling leachate.
	Acid Sulphate Soils	Low-lying land with acid-generating potential.	1) Release of acid soils can cause fish and invertebrate kills; 2) Flow on effects for biodiversity and fishing amenity - Risk factor for any developments that lead to disturbance of acid soils.	Potential for high ecological and economic cost.	1) Low-lying lands on project site contain acid soils; 2) Treatment of acid soils required as part of cut and fill activities; 2) On-going management of all dredging and on-site construction activities.
	Coastal Algal Blooms	Blooms of Lyngbya in Deception Bay (see below).	1) Blooms becoming more frequent in Deception Bay; 2) Blooms triggered and/or sustained by high levels of nutrients (P, N) and micronutrients (Fe); 3) Potential to affect the value of Deception Bay Fish Habitat Area; 4) potential impacts on human health; 5) Effects may worsen by disturbance of acid soils.	Current high economic and ecological cost.	1) Significant opportunities to reduce nutrients through re-use programme; 2) Use of best practice to ensure NEBP does not increase problems (including management of acid soils).

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Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Aquatic Habitats	River channel (unvegetated)	Subtidal sections of river relatively deep between weir and just downstream of King John Creek; then becomes shallow with limited navigability to Deception Bay.	1) Potential build up of contaminants in sediments; 2) Stratification with low levels of dissolved oxygen recorded near river bed; 3) Shallowing of navigational channel causing changes to habitat and presenting a hazard to boat operators.	1) Comprises extensive habitat within the Caboolture River estuary, much of which is upstream of NEBP project site; 2) Ecological function not well understood, but likely to be important in terms of secondary production, storage of nutrients, etc.	1) Small entrance channel to be created into marina basin, no other dredging required upstream of existing navigation channel; 2) Requirement to dredge downstream for navigation - beneficial for marina patrons and other users; 3) Dredging should minimise disturbance of habitat but would caused a temporary impact on benthic productivity; 4) Disposal and treatment of dredge spoil.
	River Banks (unvegetated)	1) Upstream of King John Creek river banks generally steep; 2) Often show extensive development, especially upstream of project site and on opposite bank to site.	1) Unregulated development and use; 2) Erosion caused by unregulated development and cattle grazing.	Extensive erosion probably adds to water quality issues.	1) Loss of small section of river bank would not represent a large loss of ecological value; 2) NEBP development needs to ensure creation of entrance to marina basin does not exacerbate erosion issues; 3) Boats traveling to and from marina must adhere to speed signs and stay within navigational channel.
	River Flats (unvegetated)	1) Extensive flats in downstream areas; used by wading birds and fish moving up from the channel with the flood tide.	None identified	High environmental value	1) Dredging plan needs to ensure minimal disturbance to this habitat; 2) No wash zones should apply for vessels traveling adjacent to flats.
	Tidal creeks	Numerous tidal creeks flow into the Caboolture R. Natural & artificial creeks on project site - often very short. Some creeks (inc. Raff Creek have sections within Fish Habitat Area).	1) Presence of pest species, particularly mosquito fish; 2) Potential to be affected by development.	Low to moderate - used as habitat by juvenile fishes, but some creeks degraded &/or have mosquito fish.	1) Minimal disturbance to Raff Creek and other creeks and channels outside the marina basin; 2) Large potential for rehabilitation/improvement by increasing tidal flushing.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
	Mangroves	1) 3 species identified in Caboolture R.; 2) most mangroves occur downstream of project site; 3) NEBP contains approximately 18.6 ha mangroves, with 0.83 ha that would be removed by the marina basin; 3) some mangroves on project site degraded by previous farming practices.	1) Potential loss due to development; 2) Small potential for erosion along Caboolture River (generally protected by peg roots that consolidate sediments).	High value (primary production & fish habitat), particularly in terms of large areas downstream of NEBP project site.	1) Minimise disturbance during construction; 2) Ensure flood mitigation measures do not lead to erosion of mangroves; 3) Large potential for rehabilitation/improvement by increasing tidal flushing and planting; 4) Large potential for nature walk through at least one area containing mangroves (and saltmarshes).
	Saltmarshes	1) 4 species identified in Caboolture R.; 2) Most saltmarshes occur downstream of project site; 3) NEBP contains approximately 7 ha saltmarshes, with 0.28 ha that would be removed by marina basin.	1) Potential loss due to development; 2) Potential for erosion along Caboolture River.	High value, particularly in large areas downstream of NEBP project site.	As per mangroves.
	Seagrasses	1) None observed in Caboolture River; 2) None observed in Deception Bay near entrance to river, with the exception of one small patch identified from the air that may have been seagrasses.	1) Extensive beds once occurred in Deception Bay, 2) Potential for recovery may be affected by Lyngbya blooms.	Low to none, given lack of seagrasses in Caboolture River.	1) Currently of no concern; 2) Future recovery of seagrasses may require adjustments to management of vessel movements or footprint and methods of maintenance dredging.

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Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Benthic diversity		1) Defined as invertebrates living in soft sediments in intertidal and subtidal parts of the Caboolture River and tidal creeks; 2) Important source of food for larger invertebrates, fish and birds; 3) Good indicator of biodiversity; 4) Good indicator of estuarine health.	Impacted by a range of human activities, including the weir, discharges from WWTPs, prawn trawling and erosion of river banks.	1) Subtidal habitat - low to moderate value - evidence of large spatial variability along the river and temporal variability in lower reaches; 2) River banks - low value; 3) River flats in downstream areas - high value.	1) Creation of entrance to marina basin - short section of river bank, low value habitat; 2) Erosion due to boat wash, requires strict management; 3) Capital dredging of navigational channel - loss of benthos with likely rapid recover, but on going disturbance due to maintenance dredging; 4) River flats - not to be dredged.
Fish & Decapods		Moderate diversity in river, particularly lower sections - comprises a variety of species that include fish, prawns and crabs targeted by fishers.	1) Lyngbya blooms may devalue status of Fish Habitat Area; 2) Ongoing poor ecological health due to high nutrient levels from WWTP's.	1) Moderate to high in river; 2) Low to moderate in tidal creeks .	1) Potential disturbance of acid soils; 2) Disturbance to tidal creeks on site; 3) Temporary loss of benthic productivity (hence food source) during capital dredging; 4) Potential for beneficial creation of habitat on site in marina basin and by rehabilitation of wetlands; 5) Potential for improvement to ecological health by re-use of treated effluent currently discharged into the river.
Conservation Issues	Whales	Baleen and toothed whales occur in coastal waters and eastern parts of Moreton Bay.	General conservation concerns, concerns related to boat strike, disturbance.	1) Low risk with respect to Caboolture River; 2) low to moderate risk with respect to Deception Bay.	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in coastal & Moreton Bay waters.
	Dolphins	At least 3 species may occur in Deception Bay and extending into the Caboolture River.	General conservation concerns, concerns related to boat strike, disturbance.	1) Low to moderate risk with respect to Caboolture River; 2) Low to moderate risk with respect to Deception Bay.	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in coastal and Moreton Bay waters.

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Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
	Dugong	1) Population in Moreton Bay; 2) Feed on seagrasses; 3) Small occurrence in Deception Bay & Caboolture River.	General conservation concerns, concerns related to boat strike, disturbance.	Low risk	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in Moreton Bay waters.
	Turtles	1) Several species may occur in Moreton Bay; 2) no nesting likely in Caboolture River; 3) no seagrasses, therefore green turtles not likely to feed in the river.	General conservation concerns, concerns related to boat strike, disturbance.	Low risk	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in Moreton Bay waters.
	Fishes	Scheduled species not recorded in Caboolture River and habitat unsuitable most scheduled species - possible exception honey blue-eye.	1) Alteration of habitat; 2) Competition with pest species such as mosquito fish.	Low risk	1) Loss of a small amount of creek habitat due to marina basin; 2) Conservation and restoration of other creeks on project site to compensate for this loss.
	Deception Bay Fish Habitat Area (FHA-013)	FHA extends from Deception Bay to Caboolture Weir and into tidal creeks but does not include designated navigation channels.	1) Poor ecological health of Caboolture River; 2) Effects of Lyngbya blooms; 3) Existing habitat disturbance (e.g. 4WD damage; rubbish dumping).	Currently low to moderate, potential to be of high value due to numerous aquatic habitats presence in FHA.	1) Minimal disturbance to tidal areas on project site; 2) Ensure minimal disturbance outside navigation channel during capital dredging; 3) Best practice management in construction and operation; 4) Opportunities to participate in and assist with management of fish habitat..

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Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
	Moreton Bay Marine Park (MBMP)	1) MBMP contains Deception Bay and extends into the Caboolture River; 2) Special consideration in terms of the MBMP in terms of a large range of human activities.	1) Broad range of issues confronting MBMP; 2) Deception Bay & Caboolture River - Lyngbya, coastal development, fishing.	Very high value, given large population & increasing usage of the resources & amenity of Moreton Bay.	1) Need to ensure the proposed development dose not adversely affect the park values; 2) Legislative requirements in respect of types of development; 3) opportunities to improve ecological health within the park.
Pest Species	Lyngbya	Naturally-occurring blue green alga (*Lyngbya majuscula*) that can exhibit large blooms, particularly during warmer months.	See above	See above	See above.
	Mosquito fish	Small alien species (*Gambusia holbrooki*) introduced from Central America. Live-bearer able to spawn several times a year.	Competition with native species in tidal creeks.	May diminish value of tidal creeks as nursery habitat for native species.	Difficult to control, but should ensure adequate flushing of any restored tidal creeks on project site.
Fisheries amenity	Recreational fishing	Anglers fish from boats throughout the estuary of the Caboolture River and from several shore-based areas.	1) Diminished ecological health of Caboolture River; 2) "Competition" with commercial fishers; 3) Potential loss of access for shore-based fishers.	High recreational value due to ready boat access, range of fish, crabs & prawns and large human population in the region.	1) Significant opportunities to improve shore-based access; 2) Importance of appropriate management of boats using the marina.
	Commercial fishing	Limited prawn trawling and mesh netting in the river.	Diminished ecological health of Caboolture River; 2) "Competition" with recreational fishers and boaters.	Moderate value	Importance of appropriate management of boats using the marina.

1.0 INTRODUCTION

1.1 Background

Northeast Business Park Pty Ltd (NEBP) has acquired 769 ha of land ("the project site") which fronts a 9 km long section of the southern side of the estuary of the Caboolture River, southeast Queensland. The project site has been subject to a variety of land uses, including pine plantation and grazing.

NEBP proposes to re-develop the project site at Caboolture as a multi-use business park designed to integrate industry, marina facilities, commercial, residential, heritage and recreational greenspace precincts. A key outcome of the proposed development is the rehabilitation of environmentally degraded areas of the site through management of greenspace networks and control of water quality entering the Caboolture River. Overall, the proposed development would occupy less than half of the total area of the project site. NEBP would also create new, but responsibly managed public access to the river. This contrasts with past practices whereby saltmarshes were damaged by 4WD vehicles and rubbish was dumped in and adjacent to the river.

The Ecology Lab Pty Ltd was engaged by NEBP to advise on the potential impacts of the development on aquatic ecology and on ways in which any negative impacts could be removed or mitigated. In addition, The Ecology Lab was also asked to provide advice on how aquatic habitats could be restored and managed in the longer term.

The Ecology Lab is a private consultancy established in 1985 and based in Sydney. We have a staff of 15 full-time tertiary-qualified aquatic ecologists and we specialise in studies on the effects of human activities on aquatic ecosystems. We undertake studies on behalf of all levels of government, government instrumentalities, private companies and private citizens. Our major clients include Great Barrier Reef Marine Park Authority, Gladstone Port Authority, Newcastle Port Authority, Sydney Port Authority, Port of Melbourne, NSW Department of Primary Industry and Fisheries, NSW Roads and Traffic Authority, Sydney Water Corporation, Commonwealth Department of Environment and Water Resources, Commonwealth Department of Defence, Australian Quarantine Inspection Services, Australian Centre for International Agricultural Research, World Fish, Warringah Council, Wyong Council, Shoalhaven Council, Snowy Hydro, BHP Billiton, Apache Energy (WA), Readymix Concrete, Walker Corporation and a variety of marina developers and operators.

Port Binnli Pty Ltd holds 50% of the shares in Northeast Business Park Pty Ltd. Port Binnli has developed marinas at Raby Bay and Mackay, Queensland. The Ecology Lab Pty Ltd (2003) was engaged to do an independent ecological audit of Mackay Marina and reported that environmental performance in the marina was excellent. A second audit done in September 2007 (in preparation) is indicating a continuation of the high environmental standards there. Environmental lessons learnt and measures adopted from Mackay and other marinas form a key component of the design and management of the proposed marina at the project site.

This document has been prepared as a specialist report to accompany an Environmental Impact Statement (EIS) for the proposed development (Cardno 2007a). It describes the aquatic habitats, flora and fauna of the study site, provides an assessment of impacts and outlines longer term environmental management for the project.

1.2 Aims and Objectives of this Investigation

The overall aim of this specialist study was to provide a specialist report with advice on issues related to aquatic ecology that could be incorporated into the documentation for an Environmental Impact Statement (EIS) for the project. The objectives of the study were to:

1. Summarise and review existing information on the aquatic habitats, resources and ecology of the study area and Caboolture River;
2. Discuss issues related to protected habitats and/or threatened species scheduled under state and commonwealth legislation;
3. Describe the aquatic habitats of the study site and surrounding areas;
4. Obtain baseline data on key ecological indicators (water and sediment quality, aquatic invertebrates and fish) at the study site and in the Caboolture River;
5. Predict and assess the likely impacts (beneficial and adverse) of the proposal in relation to aquatic ecology and associated environmental values; and
6. Prepare documentation on aquatic ecology for inclusion in a draft environmental management plan associated with construction and operational aspects of the project. This would include measures that could be carried over into conditions that would attach to approvals, environmental authorities and permits for the project relevant to aquatic ecology.

1.3 Terms of Reference (ToR) for Preparation of the EIS

The Northeast Business Park project was declared by the Co-ordinator General to be a "significant project" under the *Queensland State Development and Public Organisation Act* 1971 on 21 June 2006. This declaration initiates the statutory impact assessment procedure of the Act, which requires the proponent of the NEBP project to prepare an EIS.

Final Terms of Reference (ToR) for the preparation of the EIS were issued in 22 December 2006. Prior to finalisation of the EIS, earlier drafts of the ToR and initial correspondence supplied to the proponents provided a framework for the initiation of aquatic ecological studies. The complete ToR are presented as Appendix A in the EIS (Cardno 2007a).

1.3.1 Preparation of the Specialist Report on Aquatic Ecology

Under the ToR the Co-ordinator General is responsible for managing the environmental impact assessment process, which includes inviting government representatives to participate in the process as Advisory Agencies. Key agencies from state government advising in relation to aquatic ecology include:

- Environment Protection Agency
- Department of Natural Resources and Water and
- Department of Primary Industries and Fisheries.

In addition, Caboolture Shire Council and - at the Commonwealth level - the Department of Environment and Heritage are also Advisory Agencies for the project.

At the completion of the EIS phase (i.e. preparation, exhibition of the EIS and review of submissions on the EIS), the Co-ordinator General will prepare a report evaluating the EIS and other related material. The Co-ordinator General's report will include an evaluation of the environmental effects of the proposed project and reach a conclusion regarding approval of the project, considering the environmental effects, any associated mitigation measures and conditions that might apply to the project.

In 2005, the proponents referred the project to the Commonwealth in accordance with the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). On 12/7/2005 the project was declared a controlled action under S75 of the *EPBC Act*, with controlling provisions being: wetlands of international importance (S16 & 17B), listed threatened species and communities (S18 & 18A) and listed migratory species (S20 & 20A). The Commonwealth Minister for the Department of Environment and Heritage will undertake a separate approval process following release of the Co-ordinator General's Report. Approval will then be considered under S133 of the *EPBC Act*. The Minister may attach conditions to the approval in addition to any set by the Co-ordinator General, to mitigate impacts on matters of National Environmental Significance (NES).

1.3.2 Content of the Specialist Report on Aquatic Ecology

The ToR set out requirements for the preparation for the EIS, many of which are relevant to the preparation of this specialist report. In particular, the objectives defined for the EIS have been incorporated into those listed in Section 1.2, above, and consultation has been undertaken with advisory agencies and stakeholders relevant to aquatic ecology. The following subsections identify those components of the ToR that need to be considered in detail in this specialist report.

1.3.2.1 Accredited Process for Controlled Actions under Commonwealth Legislation

Under the ToR it is necessary to address potential impacts on matters of National Environmental Significance (NES) that have been identified in the controlling provisions when the project was declared a controlled action under the *EPBC Act* (Section 1.3.1.1). The NES report (Cardno 2007b) was prepared jointly by Cardno (terrestrial issues, Ramsar, birds) and The Ecology Lab (fishes, marine mammals and marine reptiles) and is appended in the EIS (Cardno 2007a). Broadly, issues relevant to the controlling provisions include:

- A description of the affected environment relevant to the matters protected.
- Assessment of relevant impacts and mitigation measures, including consideration of potential impacts on:
    - Values of wetlands of international importance;
    - Listed threatened species and communities; and
    - Listed migratory species.

1.3.2.2 Matters in the ToR Addressed in this Specialist Report

This specialist report addresses matters relevant to aquatic ecology that are identified specifically within the ToR. These matters are summarised and cross-referenced to corresponding parts of this report in Table ES1 and are listed in Appendix 1 of this report.

2.0 EXISTING INFORMATION ON THE AQUATIC ENVIRONMENT

As in many assessments of the environmental implications of proposed development, there is a broad level of ecological information generally available that encompasses the study site, but far less specific detail on the site itself. This report helps to identify what information is available and what is needed to assess and, in the longer term, manage the proposed development in its local ecological setting. The next section briefly summarises existing information on the site, Section 2.2 provides a more broad-scale description of the Caboolture River and Moreton Bay, while Section 2.3 considers conservation issues.

2.1 Overview of the Project Site

The project site comprises several parcels of land totalling 769 ha. The site is 7 km from Caboolture and its eastern boundary is about 4.8 km from the mouth of the Caboolture River. Cardno (2007a) provide a detailed description of the project site; a brief summary is presented below.

The project site is largely vacant and was used previously for low to medium agricultural purposes (e.g. sugar cane, pine plantation and grazing). The site has been largely cleared and now comprises little terrestrial vegetation, although mangroves are present along the sides of the Caboolture River. It is surrounded predominantly by undeveloped, low lying areas to the east and west, by low density rural residential land to the south and it is bounded by the Caboolture River to the north.

The northern area of the site along the river falls within an Ecological Corridor Designation, hence any development plan should provide for connectivity of habitat along the river. The south west corner of the site has been identified as State Nature Conservation Area. Deception Bay and the lower reaches of the Caboolture River are within a Habitat Protection zone of the Moreton Bay Marine Park and part of the Moreton Bay RAMSAR site. Parts of the Caboolture River are also part of the declared Fish Habitat Area under the *Fisheries Act* 1994. This is discussed further in Section 2.3.

2.2 Moreton Bay and the Caboolture River

2.2.1 Geographical and Hydrological Setting

Moreton Bay and its catchment have been the subject of extensive studies on water quality, hydrology, sedimentology and aquatic ecology (Tibbetts *et al.* 1998). The Caboolture River is one of several major rivers that flow into the bay, others including the Pine, Brisbane, Logan, Albert and Coomera rivers. Just to the south of the Caboolture River flows Burpengary Creek. The total catchment of Moreton Bay is approximately 18,000 km^2 (Gabric *et al.* 1998), and the catchment of the Caboolture River is 589 km^2 (Holland *et al.* 2001). Within the catchment of the Caboolture River, major land uses include natural bushland (26% of the catchment), grazing (23%), plantations (23%) and suburban and rural residential (11% - Holland *et al.* 2001).

A key feature of the Caboolture River is the presence of a weir approximately 19 km upstream of the river mouth (Figure 1). This weir creates a freshwater reservoir used to supply the township of Caboolture. It also forms a barrier to saltwater intrusion from

Moreton Bay and hence forms the upper limit of the estuary of the Caboolture River. This has important ecological implications because it reduces the amount of estuarine habitat present compared to the original river; it affects water quality, particularly salinity; and it impedes the movement of aquatic organisms within the river, many of which migrate between saltwater and freshwater.

There are relatively few creeks that flow into the Caboolture River downstream of the weir (Figure 1). Sheep Station Creek flows into the river from the south just upstream of the Caboolture wastewater treatment plant (WWTP). Goong Creek flows into the river from the north and on the opposite side of the river to the NEBP property. Raff Creek passes across the project site and into the Caboolture River. The largest tributary of the Caboolture River is King John Creek. This flows into the Caboolture River from the north and about 3 km upstream of the river mouth, at Deception Bay. The confluence of this creek with the Caboolture River is well downstream of the project site and upstream of the limit of proposed dredging of the navigation channel (Figure 1).

Descriptions and analysis of flooding, siltation and erosion are presented in the main document of the EIS (Cardno 2007a). Mean tide levels at the mouth of the Caboolture River range between 0.81 m and -0.92 m (AHD), with Astronomical Tides ranging from 1.34 to -1.26 m (Cardno 2007d). Tidal velocities adjacent to the project site are in the order of 0.3 – 0.5 m/s under normal conditions, increasing to 1.5 – 3 m/s during flooding. Bed sediments in the lower river comprise fine to coarse grained sands and clayey sands. Towards the project site fine to coarse sand with silt and clay fines prevalent (Cardno 2007d).

Cardno (2007e) investigated bank erosion within the Caboolture River. An Analysis of aerial photographs showed no significant change to the alignment of the river over the past 50 years. However, a minor downstream shift of river material has occurred in the last decade, elevating the bed level at the river mouth. An analysis of bank erosion identified, from 34 km of riverbank length (right and left banks, with NEBP being on the right bank), a total of 9 km classified as severely eroded, 12 km with some signs of erosion, 12 km with erosion not evident but with potential for erosion and only 1 km with no erosion and unlikely to be eroded in the near future.

The left bank of the river was found to be more eroded than the right; this was attributed to greater land use for grazing and to shoreline development. Areas with mangroves tended to be well-armoured, with much less erosion than more exposed banks. Cardno (2007e) prioritised erosion pressures in terms of decreasing order as follows:

- Degradation of the riparian zone caused by removal of vegetation and presence of weeds and stock
- Surface runoff
- Tidal flows
- Coastal development
- Boat wash.

PB (2007) investigated flooding issues at the project site and on the flood plain of the Caboolture River. Being low-lying, significant inundation of the flood plain occurs during the 1:100 year ARI. The topography of the project site contains low-lying lands, particularly near the river. In fact, at high tide lands adjacent to the river can be inundated (PB 2007). Raff Creek flows through the site, flowing from near the south west boundary in a north easterly direction to the Caboolture River. A large, previously-constructed channel flows from beyond the western border east northeast to the Caboolture River. There are also several smaller constructed channels on the site (PB 2007).

2.2.3 Water Quality Issues and Ecological Health

2.2.3.1 SEQ Regional Water Quality Management Strategy

Water quality within south east Queensland has received extensive consideration by government as a means of assessing and managing the ecological health Moreton Bay and the freshwater ands estuarine components of rivers within the region. The South East Queensland Regional Water Quality Management Strategy ("the Strategy") is a partnership between state, local and commonwealth governments and academic institutions that identifies management objectives and provides a framework for integrated and co-operative management actions to protect the waterways of south east Queensland (Counihan *et al.* 2002, EHMP 2005 & 2007).

Recently, the Partnership has released its draft healthy waterways strategy for the period 2007 – 2012 (Healthy Waterways 2007a). This introduces and facilitates change for a number of Action Plans within waterways of SE Queensland, and many of these plans are directly relevant to the proposed development. In particular, Healthy Waterways (2007a) provides water quality objectives for the lower, mid and upper estuary of the Caboolture River: these are discussed in Sections 3 and 4 of this report.

One initiative of the Partnership has been the implementation of an Ecosystem Health Monitoring Program (EHMP). This program includes monitoring to assess the effectiveness of management actions and provides an audit mechanism for management action. The program began in 1999 and expanded to the Sunshine Coast in October 2001. Reporting for the program includes the presentation of an Environmental Health Index (EHI) to identify whether water quality management objectives have been met (or how monitoring data compare to objectives) and this has been used to generate report card grades for various waterways and parts of Moreton Bay.

Report cards are available via the Internet and grades for the Caboolture River and other estuaries in south east Queensland are presented in Table 1. Since 2000, the estuary of the Caboolture River has graded between C- and D, which is essentially "poor" to "fair" in terms of ecological health. The grades also show a gradual decline in health over the period of assessment, with the poorer grades in 2006 and 2007 attributed to increased concentrations of nutrients in the middle and upper estuary compared to 2005, and poor riparian cover and bank stability (Healthy Waterways Website, October 2007). Previous assessments have identified low saturation of dissolved oxygen and elevated concentrations of total phosphorus. Compared to other estuaries in the program, the Caboolture River is intermediate, being similar to the Pine Rivers in 2006, better than the Logan, Bremer and Brisbane rivers, and below expectations compared to the Noosa, Mooloolah, Coomera and Nerang rivers (Table 1). In 2007, Pine, Brisbane and Logan rivers showed slightly improved grades, while Caboolture River has continued its poor showing.

It is important to recognise that water quality within Moreton Bay and the Caboolture River is affected by a range of natural and anthropogenic processes. Natural processes may include impacts associated with flooding, storm surges and inputs of nutrients from oceanic upwelling. Anthropogenic processes include alteration of run-off patterns that can lead to diffuse pollution sources and point sources associated with discharges from sewage treatment plants, industry, aquaculture facilities, etc. In addition the effects of natural processes may be mitigated or enhanced by anthropogenic factors, particularly land clearing.

It appears that, generally, there are water quality problems in the western portion of Moreton Bay. For example, according to Gabric *et al.* (1998) there is a strong east-west gradient in chlorophyll-a (an indicator of phytoplankton productivity) and other water quality indicators across Moreton Bay. These authors concluded that the western areas of the bay were degraded in terms of water quality and could be considered to be mesotrophic to eutrophic.

The discharge into the Caboolture River from the Caboolture South WWTP (Figure 1) is known to affect the water quality of the estuary, with elevated levels of nitrogen compounds (Holland *et al.* 2001 and Healthy Waterways, 2000 - 2005). In particular, high levels on oxidized nitrogen (NOx) have been recorded, leading to a condition of mild eutrophication. Under this condition, the water may become "supersaturated" with oxygen due to photosynthetic activity from phytoplankton during the day, but may become hypoxic (depleted of oxygen) at night when phytoplankton are respiring. In addition to the discharge at Caboolture, there is a WWTP that discharges into Burpengary Creek, near its entrance to Deception Bay (Figure 1).

The most recent EHMP annual report (EHMP 2007) covers the period July 2005 to June 2007. The report identifies annual inputs into the Caboolture River of 10 t and 0.2 t of nitrogen and phosphorous, respectively, from the Caboolture South WWTP (Figure 2). A further 17 t N and 3.1 t P are discharged by the Caboolture Regional WWTP into Burpengary Creek, with potential for transport of these nutrients into the Caboolture River. The Waterways Program samples surface waters (with depth profiles for some water quality indicators) at 10 sites along the estuary of the Caboolture River, from the weir to the mouth (EHMP 2007). It was found that water quality objectives for phosphorous, nitrogen, chlorophyll-a and dissolved oxygen were difficult to meet in the upper and mid sections of the estuary, but improved toward the mouth (Figure 2). The project site occurs along the middle section, with proposed capital dredging near and at the lower section. EHMP (2007) also reports, not surprisingly, that elevated levels of processed nitrogen ($\delta^{15}N = 5$ o/oo) reflected sewage-derived inputs of nutrients.

In summary, there is a well-established program of monitoring for ecological health in south east Queensland, based partly on the use of water quality indicators. The Caboolture River consistently has graded poor to fair and this can be attributed at least in part to the discharge of treated effluent from the South Caboolture WWTP. A key issue for the design and management of the NEBP will be to evaluate the potential for cumulative effects with existing uses, including the WWTP discharge and, where possible, to assist in initiatives to improve the ecological health of the estuary.

Recently, BDA (2005) have identified that, in order to meet water quality objectives of the Queensland Government, substantial reductions in current pollutant loads are required. This assessment is made particularly challenging due to expected increases in loads associated with ongoing development in South East Queensland. BDA (2005) evaluated the potential for trading schemes to deliver lower nutrients or sediments to sensitive waterways in Moreton Bay, while reducing environmental management costs. It was found that > 99% of annual sediment loads derive from diffuse sources; thus a trading program for sediments was not considered feasible for any of the waterways flowing into Moreton Bay.

On the other hand, trading schemes for nitrogen and phosphorous were considered feasible in many cases, including the estuary of the Caboolture River (BDA 2005). One analogous example considered was at South Creek, which flows into the Hawkesbury Nepean River System on the western side of Sydney, NSW (BDA 2005). Credits were derived from effluent re-use and by run-off detention and there may be possible ways in which a similar type of approach could be developed between NEBP and the waste water treatment plant just downstream of the weir. For example, there may be potential offsets available to Council by utilising open space that would be available within the study site. It is recommended that this type of approach be evaluated as part of the development of an environmental management plan for the study site. Moreover, NEBP has commissioned detailed modelling and evaluation of stormwater management for the site (Cardno 2007a). Initial assessments have indicated that stormwater management can be designed using best practice (e.g. Water Sensitive Urban Design – see also Healthy Waterways 2007b) to meet water quality objectives and hence minimise further inputs of nutrients into the Caboolture River.

2.2.3.2 Acid Sulphate Soils

Acid sulphate soils are a risk factor that must be considered when disturbing coastal soils or sediments. Environmental impacts, such as fish kills, can occur due to reduced pH (i.e. increased acidity) of water or toxic effects due to mobilisation of metals.

To date, there has been limited information on the extent or effects of acid sulphate soils in the Caboolture area. In 2006 the Caboolture Shire Council and Department of Natural Resources and Water began mapping the distribution of acid sulphate soils (1:50,000) in low-lying areas (i.e. < 5 m AHD) of the shire (ANON 2007a). Three key areas are being investigated: Beachmere, the southern end of Bribie Island and Toorbul-Donnybrook. Boreholes drilled on 367 ha at Beachmere have identified both actual and potential acid sulphate soils in that area. During the investigations for this report (i.e. literature review and consultation), no evidence was found in the Caboolture River of frequent fish kills or other impacts often associated with acid sulphate soils.

As part of the EIS for the proposed development of NEBP, an acid sulphate soils management plan has been prepared (Cardno 2007c), based on geological assessments by Coffey (2007) (appended to Cardno 2007c). The objective of the management plan is to ensure that no significant impact on the receiving environment occurs due to the disturbance of actual or potential acid sulphate soils.

Field and laboratory investigations by Coffey (2007) found that terrain within the project site at elevations of < 5 m AHD and with clayey soil has attributes consistent with the formation of acid sulphate soils. These areas also occur in locations where many of the bulk earthworks are proposed. Investigations of sediments in the area proposed for capital dredging found no actual acid sulphate soils, but it was concluded that all the sediments should be considered as potential acid sulphate soils (Cardno 2007c). The data obtained from this investigation are not only of immediate significance for the assessment of the proposed development, but provide a value supplement to the data being obtained under the Council's programme.

In summary, little evidence was found of existing environmental impacts on Caboolture River of acid sulphate soils. As with many coastal developments nowadays, the presence of acid sulphate soils in areas that would be disturbed by development poses challenges for environmental management. The potential impact of this issue in relation to the proposed development and acid sulphate soils management plan is evaluated in Sections 5 and 6 of this report.

2.2.3.3 Coastal Algal Blooms (CABs)

Lyngbya majuscula is a blue green alga that occurs naturally in Australia, but which can be present in massive blooms that affect aquatic ecology, fisheries and recreational activities. Efforts to remove Lyngbya can be extremely expensive. For example, Caboolture Shire Council removed some 6,000 t of Lyngbya from the shires foreshores, particularly around Bribie Island, in 2006/7 at a cost of more than $345,000 (ANON 2007b).

There is strong evidence that blooms of Lyngbya are triggered by increases in macronutrients (phosphorous and nitrogen) and micronutrients, particularly iron (Ahern *et al.* 2006, 2007). Furthermore, potential exists for metals released into the water due to the effects of acid sulphate soils, to stimulate Lyngbya blooms (Healthy Waterways 2007c, ANON 2007b).

Healthy Waterways (2007c) provides an Action Plan for dealing with coastal algal blooms in South East Queensland. The Action Plan Target for this is:

By 2026, in all SEQ estuarine and marine waterways, the intensity, frequency and extent of existing CABs have been reduced, no new CABs have occurred and the impacts of CAB events have been minimised (Healthy Waterways 2007c).

For this target to be achieved, several other Actions Plans will require implementation, including:

- Point Source Pollution Management Action Plan
- Water Sensitive Urban Design Action Plan
- Non-Urban Diffuse Source Management Action Plan.

One of the biggest challenges facing the Caboolture River and Deception Bay is the reduction of nutrients that are made particularly abundant by the discharges from the two WWTP's. This challenge, along with specific actions already committed to or under consideration in Healthy Waterways (2007c), provides significant opportunities for collaboration between government and the proponents of the NEBP. This is discussed further in Sections 4 and 5 of this report.

2.2.3 Aquatic Habitats

The waterways of south east Queensland contain a large variety of aquatic habitats, with key habitats in and adjacent to estuaries being mangroves, saltmarshes, seagrasses and unvegetated flats and channel beds. In addition, artificial structures, including moorings and jetty piles, also provide habitats for aquatic flora and fauna. Key features of mangroves, saltmarshes and seagrasses are discussed as follows.

Manson *et al.* (2003) reported that there were approximately 15,000 ha of mangroves in Moreton Bay. They calculated that, over the past 25 years, there have been approximately 3,800 ha of mangroves removed due to natural losses and land clearing. Most of these losses have occurred in the southern part of the bay. These losses, however, are partly balanced by the growth of mangroves in other areas, with a net loss of only about 200 ha (Manson *et al.* 2003).

There are seven species of mangroves that occur in Moreton Bay (Abal *et al.* 1998), with two species predominating in estuaries: grey mangrove (*Avicennia marina*) and river mangrove (*Aegiceras corniculatum*). Mangroves occur most often within the intertidal zone on mudflats and are inundated during most tides. River mangroves often occur further upstream than, or landward of, grey mangroves and tend to be more shrub-like in appearance.

At this stage, limited information could be found on the saltmarshes of Moreton Bay. Morton *et al.* (1987) reported that there were 3,000 ha of saltmarsh habitat in the bay, but it is not known how this area has changed over the past two decades. These authors, and Thomas and Connolly (2001) identified two common species of saltmarshes in the bay, bead weed (*Sarcocornia quinqueflora*) and saltcouch (*Sporobolus virginicus*) at sites on Coomera Island and at Meldate (Pummicestone Passage). Additionally, Thomas and Connolly (2001) identified glasswort *Halosarcia* sp. at Hervey Bay, to the north.

Saltmarshes often occur landward of mangrove forests and are inundated only by spring tides. On a yearly basis, saltmarshes in subtropical Queensland are completely submerged for only about 1% of the time, but with a strong seasonal component Connolly (1999). Thus, saltmarshes are virtually never completely inundated by tides in spring and autumn, but are inundated for 3% of the time during winter and summer.

Seven species of seagrasses have been recorded in Moreton Bay, occupying 25,000 ha in the mid-1990's (Abal *et al.* 1998). Seagrasses have shown very large variation in their aerial extent, with an estimated loss in area of 20% since European settlement (Abal *et al.* 1998). Of particular relevance to the current proposal is that there has been extensive change in the distribution of seagrasses in northern Moreton Bay over the last 30 years.

Kirkman (1978) reported large losses of seagrass in the northern part of the bay, but Hyland *et al.* (1989) reported recovery in seagrass area in Deception Bay between 1981 and 1987. At the time of reporting, these authors calculated that there were 26,673 ha of seagrass in Moreton Bay, including 3,515 ha in Deception Bay (i.e. 13% of the total seagrasses for Moreton Bay). Their mapping also shows several beds of *Zostera capricorni* on intertidal flats within the Caboolture River, extending upstream about 3 km from the mouth. By the mid-1990's no seagrasses were reported in Deception Bay or the Caboolture River.

Abal *et al.* (1998) attributed the loss of seagrasses in Moreton Bay to variety of factors, including damage from trawling, increased water turbidity and hence decreased light penetration and smothering by blooms of Lyngbya (Section 2.2.2.2).

The distribution of aquatic habitats, particularly mangroves, saltmarshes and potentially seagrasses, has significant implications for the proposed development at Caboolture. These habitats are important for a variety of organisms, including fish and invertebrates of commercial and recreational value, shorebirds and, specifically in the case of seagrasses, for dugongs and green turtles. They are given a high conservation value and they are also susceptible to a number of anthropogenic activities. As discussed below, there are opportunities for the design and management of the NEBP to maintain and in some cases restore and improve estuarine aquatic habitats in the Caboolture River.

2.2.4 Flora and Fauna

Moreton Bay and its catchment support a vast array of aquatic animals, including many invertebrates, fish, birds, marine reptiles and marine mammals (e.g. Davie and Hooper 1998) with at least 3,000 species of aquatic animals being recorded. Skilleter (1998) reviewed information on invertebrates living in soft sediments within the bay. Generally, most studies have been done in the bay itself, with additional studies done in and around the Brisbane River and southern parts of the bay. At this stage, no studies of invertebrates from the estuary of the Caboolture River have been found. The studies that have been done suggest that the benthic infauna of the western parts of the bay are quite distinct to the eastern parts of the bay; often the former tend to be more diverse and abundant. There is also some indication of seasonal patterns in benthic infauna, with major recruitment to the bay's benthic communities in August and September (Stephenson 1980, cited in Davie and Hooper 1998). It was also reported that major depletions of benthic stocks occurred in December, which was attributed to increases in mobile predators. The extent to which this pattern is consistent over time; and whether it applies to the estuaries of the bay, is unclear.

Tibbetts and Connolly (1998) reviewed studies on the nekton (i.e. fish, prawns, crabs and cephalopods) of Moreton Bay. They reported a large influx of fish into the bay in spring and summer and cited Quinn (1980) who found that species richness and abundance of fishes in Serpentine Creek peaked in April and May. Weng (1990) considered that shallow, western areas of Moreton Bay were important nursery areas for fishes typical of estuaries, but not of more marine habitats. One of his sampling sites was in the Caboolture River about 3 km from its mouth. This site was dominated numerically by silver biddies (*Gerres ovatus*), long-tailed catfish (*Euristhmus lepturus*), herring (*Herklotsichthys castelnaui*) and winter or trumpeter whiting (*Sillago maculata*).

Several studies have been done on mangrove and saltmarsh habitats in Moreton Bay. Laegdsgaard and Johnson (1995) sampled fish in two mangrove-lined shores in the western part of the bay. They found that the mangrove habitat supported species of economic importance. Morton *et al.* (1987) sampled fish in a saltmarsh channel on Coomera Island and recorded 19 species, 10 of which were of economic value. Thomas and Connolly (2001) sampled saltmarshes during the spring high tide and recorded 23 species. Sampling sites were in Pummicestone Passage and Hervey Bay. As far as is known, no surveys of fish have been done in mangroves or saltmarshes adjacent to the Caboolture River, but studies from other sites indicate these habitats are important for a variety of fishes.

Apart from invertebrates and fish, Moreton Bay supports important populations of bird waders and seabirds (Tibbetts 1998), marine turtles and marine mammals, including dolphins and dugong (e.g. Hale *et al.* 1998, Lanyon 2003). Resident populations of two species of dolphins occur in Moreton Bay. The humpback dolphin (*Sousa chinensis*) is common in western parts of the bay and Brisbane River and may enter the Caboolture River. The inshore bottlenose dolphin (*Tursiops aduncus*) occurs more in the central and eastern parts of Moreton Bay and in the vicinity Pummicestone passage. A third species, the Irrawaddy dolphin (*Orcaella brevirostris*) has been sighted in Moreton Bay, but its range is typically much further north (Hale *et al.* 1998). Lanyon (2003) reported populations of dugong (*Dugong dugon*) in Moreton Bay ranging from 503 to 1019 individuals, but these estimates were probably affected by herding behaviour. The eastern banks of Moreton Bay supported by far the largest numbers of dugong (80 – 90% of total numbers) while population estimates in Deception Bay ranged from 0 to 25 (i.e. 0 to 2.6% of the total bay population at any one survey). Thus, in terms of marine mammals, humpback dolphins require consideration in terms of potential interactions with the proposed development, while bottlenose and Irrawaddy dolphins and dugong appear to be of much less concern.

2.3 Areas and Species of Conservation Significance

2.3.1 Fish Habitat Areas

Declared Fish Habitat Areas are a form of 'multiple-use' marine protected area, protecting natural fish habitats from alteration and degradation while allowing for community use, including a continuation of legal fishing and boating activities. There are currently 71 declared fish habitat areas along the Queensland coast, providing protection for approximately 8,000 km^2 of high quality fish habitat (Web Reference #1, November 2007). Once an area is declared as a fish habitat area, it aims to provide long-term protection to all habitat types (e.g. vegetation, sand bars and rocky headlands) from direct physical disturbance and coastal development. Fish habitat areas are declared on the basis of, among other criteria, their species richness, levels of existing fisheries within the area, diversity of habitat types and presence of regionally unique fish habitat features. They are protected by the *Fisheries Act 1994* and proposed developments affecting specific Fish Habitat Areas require approval from QLD Department of Primary Industries & Fisheries.

A large fish habitat area has been declared in Deception Bay and extending into Burpengary Creek and into the Caboolture River as far upstream as the weir (FHA No. 013 – see Figure 1). The fish habitat area also includes some of the tidal creeks of the river, including Sheep Station Creek, Goong Creek, Raff Creek and King John Creek (Figs. 1 & 2). In relation to the NEBP, the fish habitat area extends along the property's frontage with the river and it extends a short way into Raff Creek on the property. As discussed later, this channel is included in the buffer set aside in the design of the development. It should be noted that, under the Fisheries Regulation (S94 (3) (c), 1995, page 120) a fish habitat area does not include the area of a channel marked by aids to navigation. Charts for the Caboolture River show a defined channel marked with navigation aids; hence there are some exclusions to the fish habitat area within the river, including areas of the channel marked for dredging in the lower estuary.

Under the draft Action Plan for Coastal Algal Blooms (Healthy Waterways 2007c), one of the Action Items (#1250) commits DPI&F to carrying out reviews of the values of declared Fish habitat Areas in the Moreton Bay catchment. The Action Description states:

Carry out reviews of the values and boundaries of Declared Fish Habitat Areas (including those affected by Lyngbya blooms) to monitor the need for amendment of Fish Habitat Areas' boundaries (e.g. if values of existing Fish Habitat Areas are degraded by continuing Lyngbya blooms).

The implication of this Action Item is that the Deception Bay FHA may need to be re-evaluated in the context of reduced values due to continuing Lyngbya blooms.

2.3.2 Threatened Species Legislation

An important component of the development of the NEBP is the consideration and management of issues related to threatened species. For this preliminary assessment, 'threatened species' refers to any species or populations listed under Part 5, Division 2 of the *Nature Conservation Act 1992* or Part 13 Division 1 Subdivision A, Division 2 Subdivision and Division 4 Subdivision A of the *Environment Protection and Biodiversity Act 1999*.

2.3.2.1 Queensland Legislation

The *Nature Conservation Act 1992* (*NC Act*) provides for the protection of all plants and animals native to QLD and the ecosystems in which they live and lists species, populations and ecological communities which have been classified as threatened in QLD. This Act integrates the consideration of threatened species into the planning process for proposed developments.

The approach taken in this report was to prepare a list of threatened species, identified under the *NC Act*, with potential to be affected by the proposal. If any threatened species are considered likely to be affected then more intensive assessments may be required.

2.3.2.2 Commonwealth Legislation

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) commenced in July 2000 and is administered by Department of Environment and Heritage (DEH). The *EPBC Act* applies to matters of National Environmental Significance (NES). As part of the ToR for the proposed development, a separate report on NES is required. An NES report addressing Ramsar wetlands, terrestrial biota and aquatic biota (Cardno 2007b) is appended to the EIS (Cardno 2007a).

2.3.3 Threatened Aquatic Species Relevant to the Proposal

Threatened aquatic species and Ramsar sites scheduled in the *NC Act* or *EPBC Act* relevant to the proposal are shown in Table 2. Relevance was considered on the basis of whether a species potentially occurred in the habitats of the Caboolture River below the weir.

One species of bony fish (honey blue-eye), two species of shark (grey nurse shark and great white shark), three species of marine mammals (dugong, Irrawaddy river dolphin, and the Indo-Pacific humpback dolphin) and five species of marine reptiles (loggerhead turtle, green turtle, leathery turtle, Pacific Ridley turtle and hawksbill turtle) in the endangered, vulnerable, rare or migratory schedules of the *NC Act* or *EPBC Act* were identified as relevant to the proposal. One Ramsar site (Moreton Bay) as listed under the *EPBC Act* was identified. Issues related to the Ramsar site, birds and terrestrial biota are addressed in the NES report (Cardno 2007b) a separate report prepared by Cardno (2007f), both of which are appended to the EIS.

2.3.4 Other Listed Species

Other considerations include 'listed marine species' (*EPBC Act*) which constitute a diverse group of marine animals. Some of them may occur rarely in and around the proposed area of development – examples being sea snakes, seahorses and pipefish and seals. Whilst they could occur in Moreton Bay they would be rare in the Caboolture River. Due to their relative isolation from the study site, any disturbance would be highly unlikely to affect populations of listed marine species. Moreover, the *EPBC Act* makes provisions relating to these species only as they are present in Commonwealth Marine Areas, and so does not apply to the study area.

3.0 FIELD INVESTIGATIONS OF THE AQUATIC ENVIRONMENT

The review of existing information on the aquatic environment (Section 2) indicates that there is limited information available on the NEBP project site and the area proposed for capital dredging. Consequently, field investigations were done to provide site-specific data on aquatic environmental values. In addition, concurrent sampling in other parts of the estuary provided a spatial and temporal context against which sites proposed for development could be assessed. The key components of the field investigations included:

- The location, distribution and extent of aquatic habitats, including marine plants (mangroves, saltmarshes and seagrasses)
- Water and sediment characteristics, including potential contamination
- Benthic invertebrates, used as a measure of ecological health and production
- Fish, including species of interest to commercial and recreational fishers.

3.1 Field Methods

3.1.1 Study Area and Dates of Sampling

Field studies have been undertaken in the Caboolture River and tidal creeks of the river, including the project site, since March 2005. The studies were designed to provide a description of the aquatic environment and associated environmental values that would assist in the process of assessment and impact mitigation; and to begin the collection of baseline data that will ultimately become part of a longer term environmental management plan, including ecological monitoring.

3.1.2 Mapping the Location and Extent of Aquatic Habitats

Aquatic habitats occurring along and immediately adjacent to the Caboolture River were identified broadly between the mouth of the river and the Caboolture Weir. This area was inspected by boat on numerous occasions during the field studies and, on 18 October 2005, a helicopter was used to inspect sites not readily accessible from the ground, to look for possible seagrass beds in the lower sections of the Caboolture River and to acquire photographs of various aquatic habitats.

Within the project site, a hand held GPS (accuracy typically 4 - 10 m; datum: WGS84) was used to mark the positions of sampling sites and determine the areas of aquatic habitats, including estuarine wetlands. In some cases the GPS was also used to provide positions of the boundaries of aquatic habitat. In the laboratory, GPS positions were entered into MapInfo GIS and overlayed on ortho-rectified and geo-referenced aerial photographs of the project site. GIS was then used to calculate areas of aquatic habitat within the project site.

3.1.3 Water Characteristics

Approximately 14 sampling sites were established and sampled from a boat along the estuary of the Caboolture River from the weir to mouth of the river (Figure 3). Sampling sites within the project site were accessed by 4WD vehicle and foot. Site access was often difficult due to the poor condition of tracks and sites were sampled opportunistically, depending on conditions at the time.

A calibrated water quality probe (Yeo-cal 611) was used to measure temperature, salinity, pH, oxidation reduction potential (ORP), dissolved oxygen (DO as % saturation and mg/L) and turbidity (ntu). At each site and time of measurement two readings were taken a few metres apart at the water surface. In the Caboolture River, where depth permitted, two measures were also taken just above the river bottom. Probe data were collected at the following times:

- 18 & 19 March 2005 (only 9 sites sampled in the Caboolture River)
- 12 December 2005
- 16 January 2006
- 25 - 26 April 2006
- 21 August 2006.
- 16, 17 and 30 July 2007

Probe data were compared to ANZECC (2000) water quality guidelines for estuaries in south eastern Australia. Guidelines were available for dissolved oxygen, pH and turbidity. The data were also compared statistically using Analysis of Variance (ANOVA) to evaluate differences in water characteristics along the Caboolture River, between surface and bottom readings and among times of sampling. The data for March 2005 were analysed separately because only nine sites were sampled at that time. Prior to ANOVA, variance homogeneity was tested for using Cochran's C Test and data were transformed as necessary to achieve homoscedasticity. Where variances could not be stabilised, significant results of ANOVA were interpreted cautiously. Where differences were detected, treatment means were examined using Student Newman Keuls (SNK) Tests. Details of these procedures are available in Underwood (1981, 1997) and Winer *et al.* (1991).

In addition to the probe data, samples of water were also collected (12/12/05 & 16/1/06) for chemical analysis of contaminants, suspended sediments, nutrients and chlorophyll-a. The contaminants included aluminium, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium and zinc; the nutrients included total phosphorous, ortho-phosphorous, total nitrogen, ammonia (as $N\text{-}NH4^{+}$) and nitrogen oxides (NOx). Two replicate water samples were collected in appropriately-prepared containers at each of six sites along the Caboolture River (Sites 1, 2, 5, 8, 11 & 13 – see Figure 3) and at three sites within the project site (Raff Creek and one creek each at the eastern and western ends of the site). Water samples were dispatched for analysis, along with chain-of-custody forms, to the National Measurement Institute (NMI) in Sydney, NSW. In most cases, water samples were analysed for their contaminants and nutrients at detection limits below the corresponding ANZECC (2000) water quality guidelines for protection of aquatic ecosystems.

As with the probe data, the laboratory results were compared to ANZECC (2000) water quality guidelines. ANOVA was used to compare sites and times of sampling (but not depths, as all water samples were collected from the surface). Cochran's C Test and SNK Tests were used as described above.

3.1.4 Sediment Characteristics

Samples of sediment were collected from the channel of the Caboolture River using a van Veen grab on 25 April 2006 and 20 March 2007. Two samples each were collected from Sites 4, 6, 8, 11, 12 & 13 (Figure 3). Attempts to collect samples at Sites 1, 2 & 3 (i.e. in the upper estuary) were not successful because the river channel comprised bedrock or very coarse sediment at these positions. Seven samples of sediment were collected by hand from tidal creeks within the project site (Figure 4).

The samples were placed in appropriately-prepared sample containers and dispatched to NMI accompanied by a chain-of-custody form. In the laboratory, samples were analysed for grain size distribution, moisture content, total organic carbon (TOC), metals (Al, As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Se & Zn) and nutrients (TP, TN, NOx & Kjeldahl nitrogen – TKN).

The data on metals were compared to ANZECC (2000) sediment quality guidelines. These data, along with grain size, TOC and nutrients were also compared among sampling sites using one-way ANOVA. Cochran's C Test and SNK Tests were used as described above.

3.1.5 Benthic Macroinvertebrates (Benthos)

Benthic macroinvertebrates (also known as benthos or benthic invertebrates) comprise a diverse variety of species, including marine worms, crustaceans and marine snails that are important indicators of the productivity and ecological condition of water bodies. Macroinvertebrates are generally defined as those invertebrates retained on a 1 mm mesh sieve. For this study, macroinvertebrates were sampled in two habitats along the Caboolture River – the river channel, which is subtidal, and the river bank, which is within the intertidal or littoral zone.

In the **river channel**, benthos was collected on 25 April 2006 using a van Veen grab at nine sites (Sites 4, 5, 6, 8, 9, 11, 12, 13 & 14 – Figure 3). These included the six sites also used for examination of sediment characteristics (Section 3.1.4). Four replicate samples were collected at each of the nine sites, washed through a 1 mm mesh sieve and preserved in river water with 8-10% buffered formalin containing Rose Bengal stain. Each sample was stored separately in a plastic bag labelled with site and replicate number, date and time of collection.

In the laboratory, samples were washed and benthos was sorted and stored in 70% ethanol. Invertebrates were then identified to the lowest practicable taxonomic level (typically to Family) and counted. Data were entered into spreadsheet, proof-read and corrected. Samples have been archived for the duration of the EIA process.

The data were compared statistically using multivariate procedures and ANOVA. The nine sites were classified into upper (Sites 4, 5 & 6), middle (Sites 8, 9 & 11) and lower (Sites 12, 13 & 14) sections of the estuary. The middle section corresponded approximately with the frontage of the Project Site. For multivariate analyses, the Primer package developed by the Plymouth Marine Laboratories (Clarke and Warwick 2001) was used to compare assemblages among river sections. Bray-Curtis similarities were computed on untransformed data and an nMDS plot was generated showing the relationship, if any, among river sections. ANOSIM was used to statistically compare river sections and, where differences occurred, SIMPER was used to identify the taxa contributing most to those differences.

A nested ANOVA was used to compare river sections and sites within sections. Data analysed included total abundance of invertebrates, taxon richness and abundance of the most common taxa. Cochran's *C* Test and SNK Tests were used as described above.

For the **river banks**, the key question of interest was the extent to which invertebrates at the point of entry from the Caboolture River into the proposed marina basin differed from other sections of river bank. Two sites each were selected along the point of entry, and upstream and downstream of this proposed point (Figure 5). Samples of sediment were collected from about the mid-tide level during the low tide on 21 August 2006. Four replicate samples were obtained by hand using a PVC corer (100 mm diameter to a depth of 20 cm). The samples were stored in labelled plastic bags with formalin and stain. To ensure that samples were collected from the same tidal level, sampling was done in as short a time as possible, hence the samples were not sieved in the field.

In the laboratory, samples were sieved through a 1 mm mesh and then sorted, identified, enumerated and archived as described above. Data were also analysed in a similar way to the river channel: here the upstream, downstream and marina entrance sections were compared with two sites nested within each section.

In March 2007 benthic invertebrates and grain size were sampled in greater detail in the navigational channel proposed for capital dredging. Replicate grabs (4 for benthos & 2 for grain size) were collected at two sites in each of five locations within the navigational channel and at two sites within each of three locations on adjacent shallow subtidal/intertidal flats that would not be dredged (Figure 8). Field, laboratory and statistical methods were as described above.

3.1.7 Fish

Fish and decapods (e.g. prawns and crabs) were sampled in two ways: tidal creeks were sampled using baited traps and the Caboolture River was sampled using a beach seine.

In tidal creeks, six replicate bait traps were deployed at tidal creeks within and near the project site (Figure 6). The traps were 45 cm long x 24 cm deep and wide and covered with 3 mm square mesh with a 5 cm opening at each end. The traps were set for periods of 2 to 3 hours during the day and were baited with a mixture of chicken pellets and tinned sardines. One the traps were cleared, fish and crustaceans were identified and counted and released, apart from a few specimens retained to verify their species identity. Fish trapping was done in January 2006 and July 2007.

In the Caboolture River, the use of a seine was constrained by tidal currents and the availability of beaches or relatively clear banks on which to haul the net. In the lower river there are extensive flats that are amenable for seining, but opportunities for seining become more limited further upstream. Furthermore, seining is restricted to mid to low tide when more river bank is available.

A seine was used to sample fish and decapods at nine (unreplicated) positions along the Caboolture River (Figure 7). The seine used was 20 m long by 1.8 m deep with a 0.25 m cod end and comprised 7 mm stretched mesh. When the net was hauled onto the river bank, fish and crustaceans were initially placed into a large tub of water, from which they were identified, counted and then released.

In March 2007 the same seine net was used to sample fish and decapods in the navigational channel and on adjacent sand flats. Three replicate seines each were hauled in the channel and flats at each of four sites (Figure 8). The flats were sampled in the upper half of the tidal cycle to ensure that fish would be able to access these areas. Field methods were as described above. Data were analysed using univariate and multivariate procedures to examine differences among sites and between the channel and flats.

3.2 Results

3.2.1 Site Descriptions

3.2.1.1 Caboolture River

The general features of the Caboolture River and the NEBP property are described in Sections 2.1 and 2.2. The inspections of the river and study site reveal a range of natural features, some of which have been altered substantially by past human activities. Features of interest are shown in Plates 1 – 6 and discussed in relation to the river and the study site.

The entrance of the Caboolture River into Deception Bay is evident from a well defined channel, with very broad sand flats within Deception Bay on either side of the entrance (Plate 1a-c). During the helicopter inspection, intertidal and shallow subtidal banks were inspected for the presence of seagrasses. One small dark patch (~ 10 m^2) was observed on the flats of Deception Bay to the north of the river mouth – this may have been seagrasses. Apart from this, no other areas that may have been seagrass beds were observed either in or near the mouth of the Caboolture River. Conditions at the time were considered ideal for observing seagrasses, if they had been present.

A significant feature of the entrance to the Caboolture River was the presence of very large stands of mangroves on either side of the river mouth (Plate 1c). There was also a large mangrove forest approximately 3 km upstream from the mouth on the northern side of the river and just downstream of the entrance to King John Creek (Plate 1d & e). Further upstream the mangrove forests cover much smaller areas. The largest, upstream mangrove forest occurs opposite the existing marina and slipway ("Monty's" – m1 in Plate 1f and Plate 5a) whilst a smaller stand occurs within the north eastern boundary of the study site (m2 in Plate 1f).

3.2.1.2 Project Site

3.2.1.2.1 Characteristics of Estuarine Habitat

Plate 2 shows several key features of the study site. The proposed entrance to the marina occurs along the section of the river with very few mangroves and largely cleared land (Plate 2a). A very small, shallow (< 0.5 m deep) tidal channel with mangroves drains from the property to the east of the proposed entrance. Plates 2b & c show significant areas of wetland towards the western end of the property. These wetlands contain mangroves, saltmarsh and some casuarinas, but they are within the proposed riparian buffer area for the development and would not be directly disturbed.

Plate 2c shows a low lying wetland inundated by high tides. A small tidal creek known as Raff Creek flows into the study site at about the middle point of the river frontage. This creek is mangrove-lined, flooding up to and below the mangroves at high tide (Plate 2d) and draining to show exposed mudflats at low tide (Plate 2e). Raff Creek has been inspected several times from the ground and fish and small shrimp have been observed there. The fish included mosquito fish (*Gambusia holbrooki*) and unidentified larval fishes. The shrimp were not positively identified but they were schooling in mid-water and may have been sibogid shrimp (*Acetes* sp.).

The tidal portion of Raff Creek habitat is included within the Deception Bay Fish Habitat Area (Figure 1) and it would be protected within a buffer as part of the proposed development. Upstream of the tidal influence, this creek forms a shallow drainage line. Further upstream and beyond the southern boundary of the study site, a series of artificial, freshwater ponds has been excavated amid residential properties (Plate 2f).

Photographs in Plate 3 show various features of the wetlands from the ground or water within the study site. The proposed entrance to the marina is in a section of the river subject to some erosion and with few aquatic plants (Plate 3a). Several small, shallow (< 0.5 m deep and typically < 0.3 m deep) mangrove-lined channels occur to the east of the proposed marina entrance. Three species of mangroves have been identified on the site – grey mangroves (*Avicennia marina*), river mangroves (*Aegiceras corniculatum*) and yellow mangroves (*Ceriops* sp.). The channel closest to the proposed entrance contains little water and is considered to be of limited value as aquatic habitat. There are several very straight drainage lines on the project site that appear to have been created artificially (see also PB 2007a). These all appear to have limited ecological value. Some of these drains are crossed by dirt roads and they have rock culverts that form a barrier to movement by fish and invertebrates (Plate 3c). There is opportunity to either remove the roads and culverts, or to replace the stone culverts with box culverts properly designed to facilitate fish passage.

Several parts of the property frontage on the Caboolture River have extensive growth of mangroves. Plate 3d depicts the entrance to the mangrove creek shown from the air in Plate 2d & e. Adjoining this creek are several saltmarshes containing mostly saltcouch (*Sporobolus virginicus*) and bead weed (*Sarcocornia quinqueflora*), but with some glasswort *Halosarcia* sp. These areas would also be largely protected within the buffer zone.

3.2.1.2.2 Mapping of Estuarine Habitats

The NEBP site presently contains 6.97 ha of saltmarsh and 18.2 ha of mangroves (Figure 9). Within the area proposed for the marina basin we mapped 0.276 ha of saltmarshes and 0.829 ha of mangroves (Figure 10). This represents a potential loss of 4.0% and 4.6% of the saltmarshes and mangroves, respectively, on the project site, and could be readily compensated for by restoration programmes on the site.

3.2.1.3 Caboolture Weir

The weir on the Caboolture River, which is well upstream of the project site, forms a major barrier to fish passage (despite the presence of a small fishway) and has significant effects on the distribution of aquatic plants and on water chemistry (Plate 4). Upstream of the weir is a large pool with freshwater plants (water lilies – Plate 4c) which are not evident just downstream (Plate 4d). In October 2005, heavy rainfall in the catchment caused the weir to overtop. At this time no aquatic plants were evident above the weir, suggesting they had either been dislodged by the flow or submerged by the deeper water in the weir pool (Plate 4e & f).

3.2.1.4 Existing Developments

Whilst the Caboolture River retains numerous natural features, there has been obvious alteration of the river by human activities. As discussed above, the weir has had a large effect on the ecology of the river. In addition, there has been alteration of the river by several developments, with potential environmental impacts (see also Cardno 2007e). Downstream of the study site is Monty's marina and slipway (Plate 5a). This contains moorings within the main river channel and along the northern boundary of the river; it also has a large hardstand area and slipway running directly into the river. Further upstream, near the entrance to Goong Creek, there is a small residential area with several large vessels moored on the side of the river channel (Plate 5b & c). In addition, there are small foreshore works, bank stabilisation and private slipways (Plate 5d). Finally, there are two Wastewater Treatment Plants, one discharging into the Caboolture River just downstream of the weir (Plate 5e) and one near the entrance to the river, discharging into Burpengary Creek (Plate 5f).

3.2.1.5 Foreshore Erosion and Degradation

As discussed in Section 2.2.1 and in Cardno (2007e), parts of the Caboolture River are in areas prone to shoreline erosion. Examples of erosion are evident along the river, particularly in places where the natural vegetation has been cleared to the edge of the river channel (Plate 6a & b). Some of these cleared areas are also used for cattle grazing and animals were often observed grazing up to the river's edge, which would exacerbate the erosion observed. In other places mangroves have provided stabilisation of banks (Plate 6c), particularly by the growth of pneumatophores (peg roots – Plate 6d) which hold the sediment together.

At the project site there is also evidence of degradation due to unauthorised access to the property. This includes debris and erosion of dirt tracks exacerbated by 4WD vehicles (Plate 6e). As discussed below, there are clear opportunities to improve the shoreline of the property boundary fronting the Caboolture River by implementing appropriate management practices.

3.2.2 Water Quality

3.2.2.1 Caboolture River

3.2.2.1.1 Probe Data

<u>Overview</u>

Results of probe measurements on five occasions are presented in Tables 3 – 7a. Salinity and occasionally water temperature were highly variable with position along the river, between surface and bottom waters and over time. Below the Caboolture Weir salinities were often very low and often remained low compared to marine waters even at the river mouth. The water adjacent to the project site typically had intermediate salinity, suggesting reasonable tidal penetration of waters from Moreton Bay.

The probe data also indicate that the Caboolture River is under considerable stress in terms of water quality, particularly in relation to concentrations of dissolved oxygen, which tended to be very low and, on occasion, very high. Turbidity was also often high, notably in

December 2005, January 2006 and April 2006. pH was marginally low in the river in December 2005, due probably to reduced salinities following a period of heavy rainfall.

Statistical Analysis of Probe Data

The data collected in **March 2005** were analysed separately to the other sampling times because fewer sites were sampled at that time. The analysis of data for surface and bottom measures taken at nine sites along the river indicated statistically significant variation both along the river and with depth (Tables 3, 8; Figure 11). Water temperature was generally less on the river bed than the surface, except at sites 1, 2 & 8 (Figure 11a). There appeared to be no gradient of temperature along the length of the river at that time. In contrast, there was a strong gradient in salinity along the river, with values approaching marine waters at the mouth of the river and declining to about 13 ppt at the weir (Figure 11b). There was a clear stratification of water based on salinity from sites 4 to 8, with salinity ranging from close to marine to estuarine at sites adjacent to the project site.

Oxidation reduction potential (ORP) showed no distinction between depths, but clear differences between sites (Table 8 and Figure 11c). Sites 1 to 4 were statistically equivalent and had a lower ORP than Site 6, which had a lower ORP than sites 7 – 9 (Table 8b). This indicates higher oxidative activity with distance upstream to the weir.

Apart from the two sites closest to the mouth of the Caboolture River, dissolved oxygen showed strong depth and distance related effects (Table 8, Figure 11d). The percentage saturation and concentrations of dissolved oxygen showed similar patterns (Table 8a, b) and only the former is graphed here. At all sites surface waters were supersaturated (i.e. > 100%): this increased to a maximum at Site 6 and remained relatively constant upstream. At most sites the dissolved oxygen levels were above the ANZECC (2000) water quality guidelines. In contrast to the surface waters, bottom waters contained much less oxygen, being less than saturated from sites 3 to 9. Sites 8 & 9 are considered hypoxic, being below the ANZECC (2000) guideline.

Turbidity showed statistically significant site and depth effects: on average, bottom water was more turbid than surface water, but due to large, within-site variability, individual sites could not be differentiated (Table 8b). There was a trend, however, for higher turbidity to occur at sites 6 and 8 (Figure 11e).

The comparison of samples taken at three sites between morning and afternoon in on 19 March 2005 showed significant temporal variability. It also suggests that there would a temporal component within the comparison of sites in the previous section, but this cannot be removed because we could not sample all sites at the same time.

For the temporal comparison, all of the water quality indicators except salinity and ORP showed some difference through time, but generally this variation was dependent on the depth or site of sampling (Table 9, Figure 12).

Water temperature showed an increase in temperature at the water surface which is consistent with solar radiation through the day; but bottom temperature remained constant (Figure 12a).

Dissolved oxygen showed different trends for percent saturation and concentration. Both indicated differences in time that were dependent on the depth of sampling, but the concentration of dissolved oxygen also showed differences with time dependent upon the sampling site (Table 9). Graphs of percent saturation and concentration between times at each depth show an increase in saturation and concentration at the surface and bottom, but the increase was greatest at the surface (Figure 12b & c). Comparing sites, the oxygen concentration was always greater in the afternoon than the morning (Figure 12d). Comparing sites in the morning indicated no difference among sites at that time, but the oxygen concentration was greater at Site 6 than at sites 4 and 5 in the afternoon.

Turbidity showed variation through time that was dependent upon the site sampled (Table 9). At sites 4 and 5 there was no difference between the morning and afternoon samples; at Site 6 turbidity was greater in the afternoon (Figure 12e).

The data collected in the Caboolture River from **December 2005 to August 2006** show a complex pattern of interactions between times of sampling, sites sampled and water depth (Tables 4–7 & 10–13). Some of the main findings are summarised as follows:

- All water quality indicators exhibited significant temporal and spatial variability (Table 10).
- Significant temporal variability in water quality indicators was equally likely in bottom and surface waters. (Table 10 and Figures 13a-d).
- Temperature and dissolved oxygen in surface water differed significantly between morning and afternoon in March, but variability within the other parameters was either not significant or only at small spatial scales (Table 11 and Figure 14).
- In December 2006 all surface water parameters exhibited significant time by site interactions indicating that temporal variability differed depending on the site of observation (Table 12 and Figure 15).
- In December 2006 all bottom water parameters exhibited significant time by site interactions indicating again that temporal variability differed between sites (Table 13).

3.2.2.1.2 Analysis of Water Samples

Analysis of metals in water samples taken from the surface indicated that levels of copper were high relative to ANZECC (2000) guidelines at all sites within the Caboolture River in December 2005 (Table 13). Zinc concentrations were also relatively high in two samples. The concentrations of nutrients in the river were consistently high compared to ANZECC (2000) guidelines, particularly for total phosphorous, total nitrogen and chlorophyll-a (Table 13). Levels of ammonia, nitrogen oxides and ortho-phosphorous were also often high, indicating a high level of bio-available nutrients. Concentrations of suspended solids were often high, which is consistent with the results for turbidity sampled using the probe.

Concentrations of aluminium and iron were relatively high in the water samples, both from the Caboolture River and the project site (Table 13). Reliable water quality guidelines for these metals in saltwater are not available in Australia (ANZECC 2000).

Statistical analysis of the data indicated that, with the exception of zinc, concentrations varied inconsistently among sites between the two times of sampling (Table 14 and Figure 16). For example, concentrations of aluminium were greater in December 2005 than January 2006 at sites 1 and 2, similar at both times at site 5 and greater in January 2006 than December 2005 at sites 8, 11 and 13 (Figure 16a). Copper, iron, total nitrogen, ammonia and total phosphorous w generally ere present in greater concentrations in December 2005 than January 2006. (Figure 16b, c, e, g & h).Chlorophyll-a showed the opposite effect, with much greater concentrations at site 1, 2 and 5 in January 2006 compared to December 2005 (Figure 16f).

Clearly, there were complex spatial and temporal patterns in water quality indicators within the Caboolture River. These patterns may have been strongly influenced by rainfall events - particularly heavy rainfall in December 2005 – just prior to sampling.

3.2.2.2 Project Site

3.2.2.2.1 Probe Data

Data for the project site indicate variable levels through time and among sampling locations (Table 15). Water temperature ranged from 9.20 C to 31.30 C, showing a much greater range than in the Caboolture River and reflecting seasonal and diurnal conditions. Salinities measured in the tidal creeks were generally indicative of brackish conditions, reflecting tidal linkages with the Caboolture River. In April 2006 we sampled salinity during a spring high tide cycle in Raff Creek and found reductions in salinity (indicating the upper limit of tidal penetration) at approximately the boundary of the Coastal Management District (Table 15; Figure 4).

With two exceptions, pH was often slightly lower than the ANZECC (2000) guideline: this probably reflects low salinity at some of the times of sampling. In August 2006 two pH values recorded near the northern sector of the project site in August 2006 were comparatively low (pH = 5.4 – Table 15e). In July 2007 pH values generally were low (pH>5.5), but at two sites pH was very low, with one readings as low as 3.90 pH units – Table 15f). This is indicative of acid sulphate conditions at that location.

As with the Caboolture River, dissolved oxygen was variable, ranging from hypoxic to hyperoxic in a few of the readings. Turbidity was generally above the ANZECC (2000) guideline (Table 15).

3.2.2.2.2 Analysis of Water Samples

ANZECC (2000) guidelines were exceeded for copper in one sample and zinc in another at the project site (Table 13). Concentrations of aluminium were relatively high in Raff Creek on both sampling occasions. Iron generally occurred in high concentrations on the project site compared to the Caboolture River. Concentrations of nutrients often exceeded the guidelines, but we cannot determine based on the data whether these elevated values are of local origin or perhaps transported onto the site from the Caboolture River by tidal exchange.

3.2.3 Sediment Characteristics

As noted above, the upper part of the estuary of the Caboolture River had either bedrock or very coarse sediments in the river channel. Sediments became fine enough to sample with the Van Veen grab downstream of the Bruce Highway crossing. It is likely that the weir has interfered with transport of sediments into the estuary from the catchment, with a deficit of sediments just below the weir.

Within the river channel, concentrations of metals were low compared to ANZECC (2000) sediment quality guidelines, although nickel and copper were slightly greater than the ANZECC Effects-range Low guidelines in four and two samples, respectively (Table 16). Whilst no ANZECC guideline exists for aluminium and iron, concentrations were often high, but very variable among samples (Table 16). The concentrations of metals and organic compounds (except total phosphorus) differed significantly between sites (Table 17). While sites 6 and 13 had the lowest values, there were no clear spatial patterns in concentrations of metals or organic compounds (Figure 17).

Samples taken from the area proposed for capital dredging had relatively low concentrations of analytes and none exceed ANZECC (2000) sediment quality guidelines (Table 16).

3.2.4 Benthic Macroinvertebrates (Benthos)

3.2.4.1 Caboolture River Channel

Grab sampling yielded a total of 28 invertebrate taxa and 737 individuals. (Table 18) Marine worms (polychaetes) had the most number of taxa (8) and individuals (368). Among the polychaetes, the Capitellidae (140 individuals) and Sabellidae (136) were most abundant. Oligochaete worms were the next most abundant taxon, with 171 individuals. The taxon richness and abundance were highly variable among sites, with a trend to greater abundance at sites in the middle reaches of the river channel (Table 19). The multivariate analyses indicated the following:

- ANOSIM indicated significant differences ($R = 0.574$, $p < 0.001$) in channel assemblages between all reaches in Caboolture (Table 20), as indicated in the separation of these localities in the nMDS plots (Figure 18a).
- The upper reaches also appear to be less spatially variable than the other locations, as indicated by the tighter clustering of samples at this locality.
- SIMPER analyses indicated that Oligochaeta, and Capitellidae and Sabellidae contributed most to dissimilarities between channel assemblages in the upper and middle and upper and lower reaches (Table 21), while Sabellidae contributed most to dissimilarity between middle and lower reach assemblages.

The univariate analyses indicated the following:

- ANOVA indicated that among channel benthos, abundances of Capitellidae, Spionidae, Galeommatidae and Oligochaeta differed significantly between localities in April 2006 (Table 22 & 23).
- Capitellidae and Oligochaeta decreased significantly in abundance from the upper to the lower reaches, while Galeommatidae increased in abundance towards the lower reaches and Spionidae were most abundant in the middle reaches (Figure 19). Other taxa exhibited only within-locality variability.

Overall, the data suggest a relatively depauperate assemblage of invertebrates in the river channel at the time of sampling, with some changes in structure along the length of the river.

Analysis of grain size data indicated that sites 4 and 6 were characterized by a large proportion of fine sediment (< 0.075 mm), while sites 8 and 9 had a more even distribution of medium and fine material (> 0.15 mm). Sites 11 and 13 in contrast, had a larger proportion of medium material (Figure 20).

3.2.4.2 Caboolture River Bank

The river bank yielded only 19 taxa with 416 individuals (Table 24). The polychaetes again had the most taxa (8) and individuals (416). The sabellids were the most abundant taxon, followed by the capitellids and aroids, with equal numbers (Table 24). Abundance and diversity appeared to be moderately variable between sites within locations, with few differences among locations (Table 25). The multivariate analyses indicated the following:

- Significant differences between bank assemblages also exist ($R = 0.295$, $p < 0.002$) although in this case, the marina locality does not differ from the downstream locality (Table 26 and Figure 18b).
- Among bank assemblages, Sabellidae, Apseudidae and Aoridae contributed most to differences between the upstream and marina locations (Table 26).
- Differences between upstream and downstream locations were mainly due to Apseudidae, Aoridae and Melitidae, while differences between marina and downstream locations were due to Sabellidae, Capitellidae and Aoridae (Table 27).
- There do not appear to be any significant differences in spatial variability within sites at each location for the bank assemblages.

Within bank assemblages only the Galeommatidae differed between localities (Tables 28 & 29), decreasing significantly in abundance from upstream to downstream (Figure 21). Most of the other taxa exhibited only within-locality variability (see Table 29 for SNK summary). As with the river channel, this one-off survey indicated a relatively depauperate assemblage of macroinvertebrates inhabiting the river bank adjacent to the proposed marina entrance.

3.2.5 Fish and Crustaceans

3.2.5.1 Tidal Channels

The bait trapping yielded 15 taxa of fish and crustaceans and a total of 2,949 individuals in January 2006 (Table 30). The most abundant species was the mosquito fish (*Gambusia holbrooki*), a pest species introduced into Australia from Central America. This species comprised 67% of the catch at that time. Other relatively abundant species included the common blue-eye (17% of the catch), Ramsay's glassfish (4.6%) and the carid shrimp, *Macrobrachium* (4.3%). The honey blue-eye, listed as a threatened species, was not collected. Several species of economic interest were collected, including yellow-fin bream, fantail mullet, mud crab and penaeid prawns.

Catches in the bait traps deployed in July 2007 were much smaller, with only three species and 148 individuals collected (albeit from a fewer number of sites). The common blue-eye was the most abundant species at that time (97% of abundance). The small catches at that time may have been due to lower pH in the creeks and/or to highly variable water temperatures (Section 3.2.2.2.1).

3.2.5.2 Caboolture River

A more diverse assemblage of fishes was collected by beach seining from with the Caboolture River in January 2006, possibly reflecting a greater diversity of habitat and the different sampling method. In all, 32 taxa and 1,816 individuals were collected by seining (Table 31). These included a range of species of economic importance, including yellowfin bream, tarwhine, mullet, flathead, whiting (2 species) threadfin salmon, prawns and mud crabs.

3.2.6 Additional Studies in the Navigation Channel

3.2.6.1 Sediment Grain Size

Samples obtained in March 2007 indicated that the sediments in channel localities consisted for medium to coarse sand with fine material (< 0.075 mm) making up between 1 and 25% of the total. Median grain size ranged from 0.20 to 0.46 mm. in the channel and from 0.20 to 0.37 mm in the tidal flats. Upstream sites were significantly coarser than those further downstream (Figure 22a). Sediments in tidal flats were not significantly different from those in the channel (Table 32), but again upstream sites tended to be coarser than those downstream (Figure 22b).

3.2.6.2 Benthic Macroinvertebrates

Macrobenthic assemblages in channel localities were distinct from those in tidal flats (Table 33), although there was some overlap between samples from these habitats as is evident in the MDS plot (Figure 23). Polychaete worms and bivalve molluscs accounted for most of the differences between these assemblages, with some groups, such as Oweniidae and Lucinidae, being ten times more abundant on tidal flats than in the channel (Table 34). The average number of macrobenthic taxa tended to decrease from upstream to downstream localities (14 to 7), a trend that was particularly evident in the tidal flats where the average decreased from 12 to 3 (Figures 24a & b). While theses trends appeared similar to those in median grain size, they did not correlate significantly. Tidal flats also supported 55% more taxa than channel sites (Figures 24a & b). All taxa exhibited significant small-scale (between-site) variability, although this was often due to only one or two sites differing from the others (Table 35; Figures 25 - 30).

April 2006 versus March 2007

Benthic assemblages in channel locations differed significantly between April 2006 and March 2007 (Table 36). This is reflected in the separation of samples from these times in the MDS plot (Figure 32). These differences were mainly due to polychaete worms, although their abundances did not differ greatly (Table 37). The number of taxa did, however, differ significantly between times, with two to three times more taxa present in March 2007 than in April 2006 (Table 38; Figure 33). Of the three most influential taxa accounting for differences between these times, only Cirratulidae differed significantly between April 2006 and March 2007, the others varying only at the scale of sites within times (Table 38, Figures 33 & 34).

3.2.6.3 Fish

Twenty-seven species of fish and four invertebrates (mainly prawns) were caught in March 2007. Catches varied from 2 to 386 individuals per haul (Table 39), most of which were juveniles (Table 40). There was no significant difference between assemblages of fish caught in channel sites and those netted over intertidal flats (ANOSIM: Global $R = 0.041$, $P = 0.19$). This is reflected in the interspersion of replicate samples from channel and flats sites in the MDS plot (Figure 35). Despite this and the finding that the number of taxa was not significantly different between groups (Figure 36), assemblages from these habitats were 68.7% dissimilar, primarily due to differences in the abundances of anchovies, southern herring and common pony fish, all of which tended to be more abundant in the channel (Table 41; Figures 37 - 39). Analyses of the number of taxa and of those species contributing 5% or more to dissimilarities revealed no significant differences between habitats (Table 42) due in part to the large variances among replicate samples. The abundances of only two species (the whiting and the common toadfish) differed significantly between sites within habitats (Table 42; Figures 40 - 44).

4.0 SYNTHESIS OF AQUATIC ENVIRONMENTAL VALUES

Based on the understanding of the aquatic environment at and in the vicinity of the NEBP project site obtained from existing information and field studies, key environmental values are summarised in Table 43 (this is also presented as Table ES2 in the Executive Summary). This table also identifies key issues from these environmental values that need to be considered in assessing the potential impacts of the proposed development.

Studies that have been done in relation to ecological health and as part of the current proposal identify ecological problems with nutrients in the Caboolture River. On this basis, it is concluded that the environmental value associated with water quality is currently low (Table 43). This is probably exacerbated by the interruption of flow caused by the weir and by a variety of other anthropogenic activities such as shoreline development, the existing marina in the river and bank erosion. The key issues for the proposed NEBP project are to work within this framework to unsure the use of best practice, to maintain tidal and flooding processes to allow flushing of river waters (and maintain connectivity within the river for biota) and to implement careful management supported by monitoring of the waters of the marina basin. On the other hand, there are significant opportunities for contributing to an improvement of the river by the re-use of treated wastewater on the project site from existing discharges.

Issues associated with water quality include the potential for disturbance of acid soils and coastal algal blooms (Table 43). Low-lying lands within the catchment of the Caboolture River, including the project site, have been shown to contain actual or potential acid sulphate soils. The implication of this is the need for careful management of construction and dredging operations as part of the environmental management of the project. Coastal algal blooms are linked to water quality and appear to be increasing in frequency in Deception Bay. These blooms diminish environmental values and are extremely costly in terms of cleanup and loss of amenity. As with general water quality issues, it will be important to ensure proper management of construction and operation of the project; but there are also significant opportunities to address this issue by re-use schemes on the project site.

There is a range of aquatic habitats in the Caboolture River with a subset of these habitats on the project site (Table 43). There are no unique or particularly extensive habitats on the project site; and all of the aquatic habitats on the site occur elsewhere in the Caboolture River. The subtidal river channel is not vegetated and is one of the largest aquatic habitats in the Caboolture River estuary, extending from the mouth of the river to the weir. Along its length it varies in terms of depth, type of substratum and biota. It provides a potential sink for contaminants, particularly those that bond onto sediment particles. It is also overlain by water that may be stratified with depleted oxygen levels. In the lower reaches shallowing of the channel has necessitated capital dredging as part of the proposal.

Much of the intertidal bank of the Caboolture River is steep, especially upstream of King John Creek, although there are several sections where large mangroves stands occur. These include a very large stand opposite Monty's Marina and a smaller stand at the eastern end of the project site. This stand would be part of the open space for the project and hence would be retained intact. Mangroves also occur along the steep river bank, but there are very few along the bank where the entrance to the marina basin would be located.

River flats (i.e. exposed at low tide) occur downstream of King John Creek and adjacent to the navigational channel. Surveys using a seine net for this project suggested that fish move up from the channel, possibly to feed or avoid predators, with the flood tide. These flats are considered to have high environmental value in the estuarine ecosystem. Key issues for the project in this area relate to development of dredging plans and potential effects of boat wash.

Tidal creeks include several large waterways (e.g. King John Creek) and many smaller channels, some of which are clearly artificial. These creeks appear to be of mixed value and are potentially diminished in value as a result of water quality and the presence of mosquito fish. Nevertheless, tidal creeks potentially can be of high value as nursery habitat and potential exists for rehabilitation of some creeks on the project site.

Mangroves and saltmarshes constitute extensive and ecologically important habitats within the estuary of the Caboolture River. The largest areas of both occur in the lower sections of the estuary with relatively small amounts at the project site (Table 43) On the site, less than 5% of each of these would be directly affected by the proposed development; a key issue will be to ensure that flood mitigation works do not affect the mangroves and saltmarshes set aside with the site. There also exists significant opportunity for a public walkway within the wetland habitats. Seagrasses were once common in Deception Bay, but have now largely disappeared. No seagrasses were recorded in the estuary during the field studies and they currently do not represent an issue for the proposed development. In the longer term, future recovery of seagrasses may require some adjustments to management of maintenance dredging of the navigational channel and boat movements.

Benthic invertebrates were used as an indicator of biodiversity and ecological health, and were sampled in soft sediments in the river channel, river banks and sand flats (Table 43). They generally showed low diversity, particularly on the river banks. They also showed substantial variability between two times of sampling in the lower reaches of the estuary. Overall, benthic invertebrates were considered to be of variable value. Issues in terms of the proposed development include the creation of the entrance to the marina basin, unstable habitat along the river banks due to erosion and impacts due to capital and maintenance dredging of the navigational channel.

Fish and decapods (which include crabs and prawns) were sampled by trapping and netting in a variety of habitats. They were moderately diverse in the main estuary but showed variable diversity within tidal creeks. This may have been due to more homogeneous habitat in the creeks, water quality problems or differences in the methods used. During sampling of water quality and habitat mapping, we also made observations of fish in the tidal creeks. Mosquito fish and toad fish (F: Tetraodontidae) were observed frequently in the creeks. Several species of economic importance were recorded in the main river channel and creeks, including bream, mullet, whiting, flathead, prawns and mud crabs.. Environmental value was assessed as moderate to high in the river but low to moderate in the tidal creeks (Table 43).

A range of conservation issues was considered with respect to aquatic ecology. These are considered in detail in the NES Report (Cardno 2007b). In general, marine mammals are not likely to be common in the area, although several species of dolphins may occur in the river and Deception Bay. As far as is known, threatened species of fish do not occur in the estuary of the Caboolture River, although there is habitat suitable for the honey blue-eye. The Deception Bay Fish Habitat Area extends from the bay up the Caboolture River to the end of the estuary at the weir. The FHA also extends into the tidal reaches of creeks, including King John Creek, Goong Creek, Sheep Station Creek and, within the project site, Raff Creek. Additionally, the coastal management District (CMD) includes lands up to the high tide level and beyond to the width of a buffer. In most cases, the FHA and CMD are preserved under the proposed development, the exception being in and around the proposed marina basin. The FHA does not include navigational channel, hence the capital dredging would not directly disturb it. The current environmental value of the FHA is assessed to be of low to moderate value, given the poor ecological health of the Caboolture River, occurrence of Lyngbya blooms and lack of management leading to destruction of wetland habitat by 4WD vehicles, dumping of cars and rubbish, etc. The proposed development provides an opportunity for enhanced local participation in, and assistance with, management of the FHA (Table 43). Notwithstanding this, the diversity and extent of habitats suggests hat if ecological health and habitat management can be improved, the FHA would have a high environmental value.

The Moreton Bay Marine Park also extends into the Caboolture River and encompasses part of the river channel fronting the project site. Most of this section would not be disturbed by the proposed development; however, the park does include the existing navigation channel, requiring careful management. The park is assessed as having very high environmental value, given the large human population in the region and increasing usage of the resources and amenity of Moreton Bay.

The study has identified two pest species within the estuary of the Caboolture River and Deception Bay (Table 43). Both Lyngbya and mosquito fish are discussed above. Construction and management of the proposed development both have a role to play in ensuring that the effects of these species are not increased, and possibly in helping to control them.

Both recreational and commercial fishing occur in the estuary of the Caboolture River. This is discussed fully in the EIS document (Cardno 2007a), but there is access available to the river from boat ramps and at several points along the shore. Previously, shore-based anglers gained illegal access to the NEBP site. People also gained access to the site to dump rubbish, including cars. Under the proposed development there is an opportunity to provide managed access which would allow shore-based fishing and prevent the vandalism observed in the past. Most of the creeks are too small to allow access and they are difficult to reach from the shore, due to swampy ground and mangroves. The estuary itself is considered to have a high environmental value for recreational fishing (Table 43) due to the availability of access (and potential for improved access), moderate diversity of target species and large human population in the region.

Sections 2, 3 and 4 of this report have described and evaluated the existing aquatic environment of the project site and adjacent waterway, extending from the Caboolture Weir to Deception Bay. These sections have also broadly introduced various aspects of the proposed development. The next two sections (5 & 6) provide a detailed assessment of the effects of the proposal and an outline of environmental management of aquatic habitats and biota.

5.0 ASSESSMENT OF ENVIRONMENTAL EFFECTS ON AQUATIC HABITATS AND BIOTA

5.1 Aspects of the Project Design Relevant to Aquatic Ecology

The proposed development is described in detail in Section 3 of the EIS (Cardno 2007a) and in various specialist reports appended to the EIS. There are two major locations that would form the basis of the development: the NEBP property (the project site) and the navigation channel in the Caboolture River downstream of its confluence with King John Creek (Figure 1).

5.1.1 NEBP Project Site

The project site consists of several parcels of land totalling 769 ha, all located on the southern side of the Caboolture River and with a frontage along the river of approximately 9 km. Broadly, the development would include:

- an industrial precinct at the western end of the site,
- two residential precincts along the southern and southeastern sides of the site,
- a marina precinct fronting the Caboolture River at the eastern end of the marina,
- a golf course and
- a very large area of open space containing terrestrial and wetland habitats.

Apart from a small section of the river frontage that would be formed to allow access between the Caboolture River and the marina basin, the river frontage of the project site would be left undisturbed, with the exception of possible rehabilitation works in some of the wetlands. Thus, only about 0.15 km of a total of 9 km (i.e. < 2%) of river frontage would be disturbed by the proposed development. Similarly, only a relatively small proportion of the Coastal Management District (CMD), which occurs within the proposed marina basin, would be disturbed. In total, less than 50% of the total 769 ha on site would be developed.

The marina basin would be perched above the level of the Caboolture River. The bed level of the marina would be at -1 m RL to provide a minimum of 3.0 m draft for vessels using the marina. To create the marina basin and to address potential flooding issues, there will be a need to undertake extensive cut and fill operations, which would alter the landform of the site. In total, the cut volume would be about 4.3 million m^3 and the fill volume would total about 3.7 million m^3. Fill would be used to build up industrial and residential precincts and infrastructure associated with the marina precinct. The Acid Sulphate Soils Management Plan (Cardno 2007c) describes management that would be implemented to address issues associated with acid soils on the project site. In particular, no fill would be imported to the project site unless it has been certified that it does not contain potential acid sulphate soils or any defined hazardous contaminant (Cardno 2007a).

There would also be a need to use fill to construct embankments for flood mitigation through the site. Flood mitigation would increase conveyance of flood waters within Raff Creek and through some of the low-lying areas of the project site. Estuarine wetlands associated with Raff Creek and in most other parts of the project site (notably along the river frontage and larger areas of mangroves) would not be developed. The exception would be within the marina basin, where a small tidal channel with some mangroves and saltmarshes would be removed. The basin itself would cover 28.5 ha, necessitating removal of < 1 ha each of mangroves and saltmarshes, as well as some terrestrial vegetation.

The construction phase of the NEBP would occur during a period of 10 to 12 years, commencing in 2009 (Cardno 2007a: Section 3, Table 10). Major civil construction works are expected to be completed in the first five years of the project. This stage includes the construction of the marina basin, extending over a period to 2011. It also includes fill of the business park, construction of stage 1 of the business park and external infrastructure (e.g. road upgrade, main services).

The excavation of the marina basin would be undertaken using only dry excavation methods. The basin would be isolated from the Caboolture River via the installation of revetment walls around the perimeter of the basin. Following excavation of the basin, a lock and weir structure would be established to connect the basin to the river. The lock system, which is used in many other marinas in Australia and overseas, would ensure that the tides in the Caboolture River are not affected by the basin. The lock system would include queuing pontoons for access to and egress from the Caboolture River and control facilities for the lock. Costs for the lock (and water quality monitoring) would be met by a "benefited maintenance levy" applied to relevant users of the marina precinct. The marina would be managed by a specific entity, the Marina Management Company.

Marina berths would be made available at various stages during the development of the project. An initial offer of 200 berths would be made available in stage 3 of the development (i.e. up to the end of 2011). Subsequent offers of 65 berths within the basin would be made in stages 5 – 15, commencing 2013/4 and ending 2023/4 (Cardno 2007a, Table 10). Thus, the occupancy of the marina and hence boating within the Caboolture River and into Moreton Bay begins with a relatively modest number of boats and builds-up in discrete stages. In addition to the wet berths, a boat stacker capable of housing up to 500 vessels would be built in stages to meet demands. There would also be a shipyard and hardstand infrastructure totalling 4.5 ha, staged over several years.

There are several specific maintenance aspects associated with the operation of the project site. Those most relevant to aquatic ecology include the following:

1. **Road network.** According to the structure plan developed for the project, most estuarine wetlands would not be crossed by roads (Cardno 2007a). The exception is an arterial road connecting MIBA and Marina precincts, which would cross Raff Creek. As shown on the structure plan, this crossing would be relatively close to the tidal limit within the creek and hence is on or close to the boundary of the Coastal Management District.
2. **Management of stormwater drainage.** As stated in the EIS (Cardno (2007a), the overall objective of stormwater management would be to preserve natural flows to the waterways and wetlands and to minimise any increases in pollutant loads. Key measures include grass swales, bioretention swales, litter and trash racks, gross pollutant traps and constructed wetlands.
3. **Management of weeds and pests.** Control of weeds and pests would be in accordance with a management plan that would require the prevention of runoff of pesticides and herbicides to stormwater drainage systems. A specific mosquito management plan would be developed which would be consistent with

relevant Queensland State Government documents relating to mosquito management. Control of mosquitoes is an important aspect of aquatic ecology because of life-cycle of these insects often includes using estuarine wetlands. Proposed initiatives for the project site include:

a. Design of earthworks to avoid creation of artificial ponds that may provide opportunities for mosquito breeding
b. Ensuring the project site is free-draining to minimise surface ponding
c. Control of potential mosquito breeding through habitat modification and minimised opportunities for onsite breeding in preference to the use of chemical control.
d. Avoiding the creation of large areas of vegetation which may provide mosquito harbourage and movement corridors from identified breeding areas near the Caboolture River into the development.

4. **Sewerage system.** This includes the following elements:

a. Previous Council planning has provided sewerage infrastructure for industrial land uses to the west of the project site (Section 3.7.5 in Cardno 2007a). The size of the proposed development, however, necessitates additional infrastructure.
b. The western sewage "catchment" of the project site, which encompasses the industrial precinct, would be connected to the South Caboolture WWTP and the entire residential precinct, and the commercial and marina precincts would incorporate the eastern catchment and be connected to the Burpengary East WWTP.
c. The sewerage trunk network has been developed maintaining the previously defines connection to the South Caboolture Waste Water Treatment Plant (WWTP). The EIS states that treated effluent would be polished to class A & A+ for reuse in irrigation and approved uses (Section 3.8.1.2 in Cardno 2007a)
d. In addition, the Burpengary East WWTP will also be needed to service a portion of the ultimate development. Whilst no specific plans are described in the EIS in terms of additional treatment for this WWTP, it is understood that any additional sewage sent to East Burpengary WWTP would assist in fast-tracking an upgrade which would include closure of the existing discharge, and capture and recycling of resultant treated effluent (email correspondence, Pt Binnli, 23/11/07).
e. Smart sewers are proposed as the centralised sewerage collection system as they are designed to limit groundwater and stormwater inflow. Concurrently greenhouse gas emissions would be reduced as the WWTP's would receive a reduced sewage load.

5. **Marina Operations.** These would be regulated and managed under a specific Site Based Management Plan (SBMP) which includes the following elements:

a. The SBMP would be developed to comply with legislative requirements including the general environmental duty which requires persons to take all reasonable and practicable measures to prevent or minimise environmental harm when undertaking activities relevant to the SBMP.

b. The SBMP would manage the conduct of Environmentally Relevant Activities (ERAs) and water quality monitoring. There are ERAs that relate to numerous activities associated with the marina and associated infrastructure, including storage of fuels and chemicals, maintenance dredging of the basin or the navigational channel in the Caboolture River, abrasive blasting of surfaces, storage and mooring of vessels, etc.

c. The SBMP would also address issues related to contingency plans for clean-up of spills; details of sewage disposal for vessels using the marina, details of predicted vessel movements in the Caboolture River including the maximum displacement and draft of vessels to be catered for by the proposed marina, etc (Cardno 2007a and Appendix Y1 of the EIS).

6. **Maintenance dredging of the marina basin.** Some sediment would be transported to the marina basin from terrestrial runoff, inflow from the turnover pumping system and lock operation, and from flooding. Some of these potential sources would be controlled by on-site measures, such as sediment erosion control during construction. Preliminary estimates indicate sedimentation in the order of 2 mm/yr (Cardno 2007a) and on this basis de-silting of the basin would not be required for at least 250 years.

5.1.2 Capital Dredging in the Navigational Channel of the Caboolture River

Capital dredging - and subsequent maintenance dredging - of the navigational channel would occur along a 6.5 km long section of the Caboolture River just downstream of its confluence with King John Creek. This is shown approximately in Figure 1 of this report and in more detail in Cardno (2007a). The capital dredging would occur within a channel width of 50 m, thus the total area of dredging would be in the order of 32.5 ha.

Approximately 545,000 m^3 would be dredged from the navigational channel for the capital works dredging. Dredging would be done using a cutter suction dredge, which entrains a slurry of water and sediment from the river bed. This method tends to inhibit the creation of a turbid plume. Nevertheless silt curtains would be deployed during dredging as a precautionary measure to prevent any turbid plumes escaping into the river channel (Cardno 2007a).

The dredged channel would be excavated to a depth of -4.25 m AHD, giving a depth of 3.0 m at LAT. This will increase the depth of the river bed by amounts varying from 0 m to 2.8 m along the channel. The slopes of the dredged channel would be formed to 1:3. The material to be dredged would be piped to the NEBP project site to be used as fill. The pipeline removing dredged slurry would extend upriver approximately 500 m beyond the upper limit of dredging and would exit from the southern bank of the river at the existing easement for Farry Road. The pipeline would then extend about 1.5 km along this easement to the southeastern corner of the project site.

5.1.3 Maintenance Dredging in the Navigational Channel of the Caboolture River

According to Cardno (2007a & 2007d) there would be a need for ongoing maintenance dredging of the navigation channel. It is predicted that approximately 4,000 m^3 of sediment would need to be dredged to a depth of about 0.5 m every two to three years. The greatest need for maintenance dredging is predicted to be at chainages 4,000 to 5,000 on dredge drawing No. 7900/33/01-102 (Section 3.5.4.2 in Cardno 2007a). This reach includes a large bend in the current navigational channel that travels close to both sides of the river and extends over about 1 km from just upstream of the public boat ramp.

Additionally, some 220,000 m^3 of sediment would need to be removed by dredging every five years.

The material deposited in the navigational channel after capital dredging would initially have a high percentage of sand due to the redistribution of material from adjacent banks (Cardno 2007a, d). In time the proportion of fines would increase as the dredged channel approaches dynamic equilibrium with the adjacent banks and flow regimes. Flood events would also affect deposition of materials in the channel and as such predictions are difficult regarding the amount of material to be dredged following the initial capital dredging (Cardno 2007a).

Spoil obtained from the maintenance dredging would be disposed of in one or more of the following ways:

- Up to 2018 the maintenance spoil would be deposited at the same site as the spoil from capital dredging, which is on the NEBP project site.
- After 2018, the spoil would be disposed of either by sale for construction or fill, or on land purchased by the proponent specifically for disposal.
- Cardno (2007a) note that the State government will be preparing strategic policy advice on disposal of dredge spoil on a state-wide basis, hence further guidance on disposal of the maintenance spoil should be available by the time that disposal is no longer available on the project site (i.e. > 2018).

5.2 Construction Issues

5.2.1 Impacts Associated with Development of the Project Site

Less than half the project site would be developed as part of the project and much of the undeveloped portion contains aquatic habitat. There are three aspects of the cut and fill operations that would, or have the potential to, affect aquatic habitat on the site: creation of the marina basin, flood mitigation works; and disturbance of acid sulphate soils.

5.2.1.1 Construction of the Marina Basin

The proposed Marina basin covers an area of about 28.5 ha and includes two small tidal creeks and a short section of river frontage of about 120 m (Figure 10). These creeks are very narrow and shallow, and support small amounts of mangrove and saltmarsh habitat. Removal of these creeks constitutes a loss of less than 5% of each habitat on the project site. Sampling of fish and decapods indicated these creeks are of limited value in terms of fish habitat. Therefore, loss of this area is considered to be of minor significance, with the potential to be more than compensated for by creation of fish habitat in the marina basin and rehabilitation of degraded wetland elsewhere on the site.

The method of construction of the marina basin would ensure isolation of the works from the Caboolture River until the basin was cut and formed. Water collecting in the basin during construction would be pumping into the river only if it were of an appropriate quality.

5.2.1.2 Flood Mitigation Works

Modelling of flooding in the existing environment and with flood mitigation measures installed on the project site indicates that flooding within the catchment of the Caboolture River would essentially remain unchanged as a result of the proposed development (PB 2007).

Flood mitigation works are necessary on the site to allow for conveyance of floodwaters around infrastructure. The works involve:

- Four cuts in the landform to create by-pass channels. In essence, none of these would be in estuarine wetlands, although the edges of two cuts are at the CMD boundaries for two arms of Raff Creek.
- Construction of eight earthen flood diversion banks. Most of these also occur beyond estuarine wetlands (and hence outside the CMD). However, one large embankment would occur within the CMD in the central portion of the project site and another small embankment would extend between the northeast corner of the marina precinct and Raff Creek. Both these embankments have the potential to cause a loss of saltmarshes and mangroves as a result of emplacement of the embankment and accessing the site to deposit earth there.

If the precise details of the embankments and means of construction are not available for assessment at this time, it is recommended that a more thorough assessment of the proposed flood mitigation works on aquatic habitats be done at the detailed design stage of the project.

5.2.1.3 Acid Sulphate Soils

Potential and actual sulphate soils have been located both on the project site and in the navigational channel proposed for capital dredging. Cardno (2007c) have addressed the matter of acid soils and have recommended measures to identify and treat all suspect soils and sediments. Based on their specialist advice, acid soils should not impact on the aquatic environment, although a precautionary approach warrants that this issue be incorporated into environmental monitoring of aquatic habitats and biota.

5.2.2 Impacts on the Caboolture River Resulting from Capital Dredging

The navigational channel that is proposed to be dredged occur outside the designated Fish Habitat Area (FHA-013) and hence this would not be disturbed directly by the project. The channel is, however, within the Moreton Bay Marine Park and all efforts would be made to minimise any impacts within the park.

The use of a cutter suction dredge would minimise water quality issues within the river, as sediments would be removed as a slurry and pumped away from the river for treatment and use on the project site. The treatment of sediments on site would be subject to stringent environmental management in terms of runoff and acid soils, as described in Cardno (2007a).

No seagrasses have been observed in or adjacent to the navigational channel, hence no beds are predicted to be lost as a result of dredging. Similarly, mangroves and saltmarshes are naturally set back from the channel and would not be directly disturbed by dredging. The pipeline transferring slurry from the dredge site to the project site would pass over land and

5.1.3 Maintenance Dredging in the Navigational Channel of the Caboolture River

According to Cardno (2007a & 2007d) there would be a need for ongoing maintenance dredging of the navigation channel. It is predicted that approximately 40,000 m^3 of sediment would need to be dredged to a depth of about 0.5 m every two to three years. The greatest need for maintenance dredging is predicted to be at chainages 4,000 to 5,000 on dredge drawing No. 7900/33/01-102 (Section 3.5.4.2 in Cardno 2007a). This reach includes a large bend in the current navigational channel that travels close to both sides of the river and extends over about 1 km from just upstream of the public boat ramp.

Additionally, some 220,000 m^3 of sediment would need to be removed by dredging every five years.

The material deposited in the navigational channel after capital dredging would initially have a high percentage of sand due to the redistribution of material from adjacent banks (Cardno 2007a, d). In time the proportion of fines would increase as the dredged channel approaches dynamic equilibrium with the adjacent banks and flow regimes. Flood events would also affect deposition of materials in the channel and as such predictions are difficult regarding the amount of material to be dredged following the initial capital dredging (Cardno 2007a).

Spoil obtained from the maintenance dredging would be disposed of in one or more of the following ways:

- Up to 2018 the maintenance spoil would be deposited at the same site as the spoil from capital dredging, which is on the NEBP project site.
- After 2018, the spoil would be disposed of either by sale for construction or fill, or on land purchased by the proponent specifically for disposal.
- Cardno (2007a) note that the State government will be preparing strategic policy advice on disposal of dredge spoil on a state-wide basis, hence further guidance on disposal of the maintenance spoil should be available by the time that disposal is no longer available on the project site (i.e. > 2018).

5.2 Construction Issues

5.2.1 Impacts Associated with Development of the Project Site

Less than half the project site would be developed as part of the project and much of the undeveloped portion contains aquatic habitat. There are three aspects of the cut and fill operations that would, or have the potential to, affect aquatic habitat on the site: creation of the marina basin, flood mitigation works; and disturbance of acid sulphate soils.

5.2.1.1 Construction of the Marina Basin

The proposed Marina basin covers an area of about 28.5 ha and includes two small tidal creeks and a short section of river frontage of about 120 m (Figure 10). These creeks are very narrow and shallow, and support small amounts of mangrove and saltmarsh habitat. Removal of these creeks constitutes a loss of less than 5% of each habitat on the project site. Sampling of fish and decapods indicated these creeks are of limited value in terms of fish habitat. Therefore, loss of this area is considered to be of minor significance, with the treatment for this WWTP, it is understood that any additional sewage sent to East Burpengary WWTP would assist in fast-tracking an upgrade which would include closure of the existing discharge, and capture and recycling of resultant treated effluent (email correspondence, Pt Binnli, 23/11/07).

5.3.3 Weeds and Pests

The EIS has identified the need to control harmful impacts that may be associated with the treatment of weeds and pests at the project site. Treatment of mosquitoes would be addressed by controlling habitat vital to their life cycle, with use of chemical control not a preferred approach (Cardno 2007a; see also studies by Dickman 2000, Weston *et al.* 2006, Hurst *et al.* 2007). However, control of mosquitoes by controlling or altering habitat could affect estuarine wetlands (e.g. draining of ponds used as refugia by larval fishes). Such impacts are manageable but need to be considered explicitly in management plans. For example, any proposal to drain specific ponded areas should be accompanied by an assessment of impacts. In some cases, improving tidal exchange to ponds may retain habitat for fish and aquatic invertebrates whilst assisting in the control of mosquito larvae.

Two other pests need also to be assessed in relation to the project. Mosquito fish (*Gambusia holbrooki*) were introduced into Australia and many other countries in the belief that they would control mosquito populations. These fish have been found to be very successful competitors for aquatic resources and are often considered to be a pest species. They can thrive in both fresh and brackish water and appear to prefer still waters. They occur in tidal channels and pools on the project site and in other parts of the Caboolture River. Creation of constructed wetlands could be used by mosquito fish and management plans should include provision to inhibit, as best as possible, the spread of this species.

Lyngbya majuscula is a blue green alga that causes coastal algal blooms in Deception Bay and other parts of Moreton Bay. Measures proposed in relation to construction and management of the site are aimed at minimising the release of nutrients which could in turn lead to or enhance blooms. In addition, the NEBP development should ensure that the risk of micro-nutrients (e.g. iron) into the Caboolture River is minimised. This can be achieved by measures already proposed to address acid soils (disturbance of which could dissolve and hence mobilise iron compounds) and site runoff. These measures should be accompanied by water quality monitoring specifically targeted at metals and nutrients. Second, the additional loads of effluent from the East Burpengary WWTP could exacerbate blooms, hence the importance of fast-tracking upgrades of that system (see above).

5.3.4 Operation of the Marina

A thorough Site Based Management Plan (SBMP) governing the operation of the marina is described in Cardno (2007a) and covers a large range of activities, management, monitoring and funding arrangements. There is also a management plan developed specifically for the marina basin to cover monitoring and aquatic habitats. Given the exemplary operational activities of the Mackay Marina (The Ecology Lab 2003) it is considered that the operation of the marina at NEBP would have a strong likelihood of being able to manage operational issues in an environmentally effective way. Other specific issues associated with the ongoing operation of the marina include:

- **Requirements for maintenance dredging in the marina basin.** As described in Cardno (2007a), it is predicted that there would be minimal deposition of sediments within the marina basin, hence requirements for maintenance dredging would be infrequent, to say the least.

- **Lock operation and queuing pontoons.** The use of a lock system for access by boats to and from the marina controls potential impacts of the basin on the tidal regime of the Caboolture River. If uncontrolled tides flowed into and out of the marina, changes would occur in the tidal penetration into and flushing of the river. Lock systems are common in many areas to avoid tidal impacts, with locks built in SE Queensland, Darwin Harbour and many countries overseas. It is proposed that two large queuing pontoons would be installed on each side of the lock (i.e. 2 each in the river and marina basin). The pontoons on the river side of the lock would be recessed into a small embayment and hence would not present an issue for navigation upstream and downstream by other boat users.
- **Water and habitat quality of the marina basin.** Several issues are important in terms of the quality of the habitat within the basin:
  - Fish and invertebrates would be able to move into and out of the marina basin via the lock system and possibly also via the turnover pumps proposed for replacing water in the basin.
  - Habitat for aquatic biota would be provided around the marina berths, on the bed of the basin and around the shoreline, especially along the frontage of the section of environmental protection zone, between the basin and the river.
  - It is expected that the aquatic biota within the basin would be a subset of that occurring in the adjacent river habitat. Species expected to inhabit the basin include mullet, bream, toadfish, mud crabs and prawns. The substratum (bed) of the basin would support marine worms, amphipods and molluscs, with more diversity if the bed consists of soft sediment such as mud or fine sand, rather than compacted clay.
  - There is scope for enhancing aquatic habitat along the environmental protection zone by planting aquatic flora, for example reed beds (*Phragmites*).
  - Apart from the habitat of the basin itself, it would be critical to ensure adequate water quality. The pump system, wind action and movements of vessels would help to mix the waters of the basin and inhibit stratification. Potential build up of contaminants of concern in the water and sediments of the basin would be mitigated somewhat by the pump system and the staging of availability of marinas berths over time, which allows for monitoring and anticipation of any problems. It is recommended that the pump system be modularised so that it can be increased if it is found that greater water exchange is necessary to maintain water quality; and that water quality monitoring include measurements of nutrients, coliform bacteria, oil and grease, and metals such as copper and zinc (which is sourced from sacrificial anodes) both in the marina basin and the adjacent river.
- Vessel movements in the Caboolture River. Management plans and education of partons of the marina are proposed to ensure that vessels travel at appropriate speeds and within the navigational channel when travelling in the Caboolture River.

5.3.5 Management of Shoreline and Wetland Access

A significant positive benefit of the proposed development is that there would be far greater control on shoreline access than is currently the case. This would help to enhance the management and ultimately the value of the Fish Habitat Area and improve the amenity of the region.

In addition to shoreline access, there is potential to create an environmental walkway through some of the mangrove and saltmarsh wetlands of the project site. Similar walkways have proved to be very popular in several coastal towns and would provide an additional recreational and educational outlet for local residents and marina patrons.

5.3.6 Maintenance Dredging of the Navigational Channel in the Caboolture River

Maintenance dredging would be required on a relatively frequent basis, with small amounts being dredged every two to three years and a large campaign required every five years. Key issues in relation to aquatic ecology include the following:

- **Water quality including treatment and disposal of slurry water.** Effects on water quality of the Caboolture River are likely to be similar to or less than the capital dredging program. Depending on monitoring the effects of the capital dredging on water quality, it may not be necessary to use silt curtains. With the capital dredging and with maintenance dredging up to 2018, the project site would be used for storage of the dredge spoil and treatment of the slurry water. Following 2018 it may be necessary to use a different site for dewatering prior to sale or disposal and potential impacts associated with that site would need to be assessed.
- **Ongoing disturbance to biota of the river channel.** Maintenance dredging would constitute an ongoing disturbance, albeit at a small scale, to biota occurring in the river channel. Removal of sediment to a depth of 0.5 m below the bed surface would be sufficient to remove most benthic invertebrates in the path of the dredge head. In periods between dredging there would be rapid recolonisation – monitoring the effects of capital dredging would provide a firm basis for understanding the best ways of managing the maintenance dredging in order to have minimal ongoing effects.
- **Impacts on adjacent sand flats.** The EIS indicates that sediment would be transported into the navigation channel to replace the sediment removed by dredging (Cardno 2007a). The extent to which this is likely to occur has not been determined, however, on the basis of the information now available, it must be concluded that loss of bank/flat habitat adjacent to the channel could have a major impact for the following reasons:
    - The flats are relatively productive and provide a habitat for benthic invertebrates and fish likely to feed (or avoid larger predators) over the flats at high tide.
    - The flats provide protection for mangroves and saltmarshes on the landward side of the flats. Therefore, loss of the flats may expose marine vegetation to erosion.
    - The flats, being outside the navigational channel, are within FHA-013. Impacts to the flats would also extend the extent of disturbance within the Moreton Bay Marina Park.

It is recommended that further detailed modelling of sediment movements be done to identify the extent of potential impacts on the flats adjacent to the navigational channel. A possible long term solution to the matter may be to place the dredged sediment onto the flats so that these sediments are not lost from the ecosystem.

5.4 Ecologically Sustainable Development (ESD)

The EIS places a great emphasis on the design of the proposal as being ecologically sustainable (Section 3.1 in Cardno 2007a). Given the successful management of the Mackay Marina in terms of aquatic ecology (The Ecology Lab 2003) there is a strong likelihood that operational procedures during construction and operation of the facilities (including implementation of SBMPs) will be effective in protecting the aquatic environment. The majority of the features associated with the development are considered, in terms of aquatic ecology, to be ecologically sustainable.

Core objectives of ESD include the following:

- Enhance individual and community well being and welfare by following a path of economic development the safeguards the welfare of future generations;
- Provide for equity within and between generations;
- Protect biological diversity and maintain essential processes and life-support systems

One of the key guiding principles for considering development in terms ecological issues is the precautionary principle:

- Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by :
    - Careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and
    - An assessment of the risk-weighted consequences of various options.

As identified in the EIS, there are risks associated with the construction activities. In the context of aquatic ecology, these risks are related to management of water, acid soils and dredging operations. Each of these is considered in a precautionary context, with commitments from the proponents for monitoring and management. Operationally, various processes and procedures are identified to ensure consideration of the aquatic environment. In particular, monitoring of a range of potential contaminants of concern would be implemented as part of the SBMP for the marina. The staging of availability of marina berths provides an orderly means of assessing changes in the aquatic environment of the marina basin and can be used to set and measure performance indicators of ecological health. In addition, sewage pumped to South Caboolture WWTP would be treated to a high standard and re-used. It is understood that the increased sewage flows to East Burpengary WWTP would trigger fast-tracking of the upgrading of treatment and disposal there.

Two other issues associated with the proposed development warrant consideration of a precautionary approach:

1. The construction of two of the eight flood mitigation embankments which extend into the coastal management district. If these significantly affect the flow of flood

and tidal waters within wetlands, then they may cause a loss of wetland habitat and diminish, on a small scale, the value of the Fish Habitat Area. Access to the embankment sites during construction may also impact upon wetland habitat. A precautionary approach suggests that the siting of the embankments be done to minimise the loss of wetland habitat an to minimise any changes to normal water movement that could adversely affect to wetland.

2. Effects of capital and ongoing maintenance dredging on flats adjacent to the navigational channel in the lower reaches of the Caboolture River. The predicted replenishment of sediments in the navigational channel, including a contribution from adjacent banks, represents potential for impacts beyond the channel and hence within FHA-013. A precautionary approach suggests further modelling of siltation processes be done to identify exactly where and by how much the adjacent flats could be affected by ongoing dredging. This could then be used to define more precisely the dredging program.

In summary, the project has been designed to be consistent with principles of ESD and measures have been identified within the EIS to address sustainability during construction and operation. Clearly many of the proposed changes are not easily or feasibly reversible. However, some impacts associated with maintenance dredging and other issues related to water quality (e.g. control of stormwater and acid sulphate soils) are reversible. In particular, the current poor ecological health of the Caboolture River may be reversed to some extent by the proposal and this represents a major positive benefit.

As may be expected in a project of this size, there are some additional measures that need more detailed consideration. These include the location of some flood mitigation embankments and the effects of capital and maintenance dredging on adjacent flats in the lower estuary of the Caboolture River.

5.5 Environmental Values and Management of Impacts

This section brings together Sections 4 (Environmental Values), 5.1 (Project Description) and 5.2 & 5.3 (Construction and Operational Impacts) and 5.4 (ESD).

5.5.1 Landform

Three aspects of landform are relevant to aquatic ecology: creation of the marina basin, flood mitigation embankments and dredging of the navigational channel.

The marina basin would create 28.5 ha of aquatic habitat that is connected to the Caboolture River via the lock system and the pumping system designed to provide additional exchange of water between the basin and the estuary. The basin would cause the loss of a small amount of mangrove and saltmarsh habitat, including a narrow tidal channel. Field studies done as part of the EIS indicate a low value for the channel, hence the loss would be small.

Construction of the basin is proposed to ensure it is kept isolated from the estuary until its construction is completed. Disturbed sediments would be assessed for acid sulphate soils and treated as appropriate. Any dewatering of the basin would be subject to control to ensure suitable water quality prior to discharge. Management of this process could be enhanced by monitoring both the water to be discharged and the ambient river conditions.

The marina basin would develop a flora and fauna as a subset of the adjacent estuary. Marina structures would provide habitat for fish and invertebrates and there is cope for habitat enhancement on the northern side of the basin. As there would be no tidal range within the basin, mangroves may not be suited for this area; however, reed beds backed by some saltmarshes (e.g. salt couch) may be appropriate.

Operational practices in the marina would be governed by the SBMP which would include monitoring of water quality. A water quality plan has already been developed as part of the EIS (Cardno 2007a). It is recommended that management be linked to the various stages of the development of the marina, as the number of berths would increase in stages. This would also the measurement of changes before and after each new stage. Monitoring of water and sediments is recommended within the basin and in the adjacent estuary (see Section 6).

Two of the proposed flood mitigation embankments would be built into wetlands on the project site. These have potential to cause damage to the wetland in three ways:

- Access during construction
- Emplacement of the embankments which may cover wetland habitat
- Changes to water flow into and around wetland habitat.

It is recommended that the embankments be placed to avoid wetlands. If this is unavoidable, the wetland that would be affected should be carefully assessed. If there is scope for adjusting their position, then this should be considered based on an assessment of their value. Again, there may be some scope for orientation of the wetlands in order to minimise an adverse effects on flow of water to the wetlands. These measures should be considered as part of the detailed design of the development.

5.5.2 Water Resources

The construction of the marina basin represents an increase in the water resources available for ecological processes, with a small amount lost due to the removal of a tidal creek. Given that there are numerous other tidal creeks in the system (with others, including Raff Creek) at the project site), this loss is considered to be small.

5.5.3 Coastal Environment

Key issues are assessed as follow:

- Specialist studies on flooding and tides indicate little change as a result of the proposed development.
- The entrance to the marina represents a small loss of river frontage; by far the major proportion of the site’s frontage would not be developed under the proposal.
- Boat movements within the river would be strictly regulated and supported by education of marina patrons. Hence, this potential source of shoreline erosion would be incorporated into management of the project.
- There is a risk that capital and ongoing maintenance dredging would cause some erosion of adjacent flats in the lower Caboolture River. It is recommended that this be evaluated further as part of the detailed design of the project.

5.5.4 Noise, Vibration and Artificial Lights

Noise, vibration and artificial lighting would not be an issue at the project site during construction due to the isolation of the marina basin from the estuary and the buffer set between the river frontage and development. During operation, there would be noise and vibration associated with vessel movements. Speed limits would be strictly limited both in the marina and river which should help to minimise noise and vibrations. Given that such noise/disturbance is normally associated with marinas and that marinas have been shown to support a varied flora and fauna (e.g. The Ecology Lab 2003), this is not expected to be problematic.

There would also be lighting associated with the marina structures and probably at the lock and queuing pontoons. Again, lighting is normally associated with marinas. Even with lighting, there would be a shadow under the berths due to boats and the berth structures. Moreover, the behaviour of many organisms would be to habituate to lighting; hence impacts are likely to be small. There may also be street lighting on the road crossing of Raff Creek. This is likely to have little effect on biota, but could be minimised by ensuring that lights are directed away from the water.

Dredging machinery would have both noise, vibration and, depending on hours of operation lighting. The lower portions of the Caboolture River already have substantial noise and vibration associated with the operation of small run-about boats which can be noise and very fast. In the context of the noise environment, it is considered that noise and lighting associated with dredging activities would have little impact on the aquatic environment. The EIS doers not indicate that there would be any need for blasting in the aquatic environment, hence this type of impact would not occur.

5.5.5 Nature Conservation

5.5.5.1 Juvenile and Aquatic Species

As discussed in Section 4 of this report, ecological values in relation to water quality and tidal creeks is low to moderate within the Caboolture River. Notwithstanding this, features of the design of the project aim to improve the quality of the aquatic habitat both on the site and in the estuary. Under the current situation, there would be a small loss of creek habitat on the site; Raff Creek, the largest tidal creek, would be preserved and the marina basin would provide a large area of aquatic habitat. On this basis, the project site would have little negative impact on juvenile aquatic species.

Dredging in the navigational channel would cause loss of benthic invertebrates and potentially some slow-swimming fish unable to avoid the dredge head. The sedimentary habitat remaining after dredging would be colonised rapidly by invertebrates hence impacts are predicted to be short-term. In the longer term, additional consideration needs to be given to potential impacts on adjacent flats.

5.5.5.2 Seagrasses

No seagrasses have been identified in or near the entrance to the Caboolture River, hence under the current situation seagrasses would not be affected by the proposal. In the longer term, improvements to water quality by increased treatment of effluent and re-use schemes may reduce Lyngbya blooms which could have a beneficial effect on seagrasses in Deception Bay.

5.5.5.3 Ecology of the Marina Basin

Exchange of water would be facilitated by vessels entering and leaving the lock and by the pumping system. This would lead to colonisation and migration of aquatic organisms to the basin although the timing of this is difficult to predict. The marina basin would not have a tidal range, so would be few, if any intertidal organisms colonising that habitat. Apart from this, it is predicted that the basin would develop a flora and fauna that is a sub-set of the adjacent estuary.

Habitats within the marina basin include the solid surfaces of marina structures and the foreshores. The northern foreshore, however, could be developed with a sloping shoreline and wetland vegetation such as reed beds. The basin floor would be colonised by benthic invertebrates, which would live and in the substratum. The extent to which organisms would bore or burrow into the substratum would depend on the bed itself – a harder substratum would have fewer burrowing and boring organisms. Siltation is predicted to be very small (~ 2 mm/year). This has two consequences. First, there would be virtually no need for maintenance dredging, so the bed would essentially remain undisturbed. Second, the very gradual build-up of sediments would provide habitat for benthic organisms, which are themselves often very small.

Management of the marina basin would be part of the SBMP, which includes general management of operations, responses to spillages and any other environmental mishaps, etc. The SBMP also includes monitoring of water quality, which should include a full range of nutrients and potential contaminants of concern. The staged approach to offering berths has a clear advantage as it allows ongoing monitoring of performance and adjustments to operations at each stage of development.

5.5.5.4 Dredging and Spoil Disposal

A minor amount of dredging would be required along the frontage of the project site to allow vessel access to the marina basin. This section of shoreline shows signs of erosion and previous human impacts (e.g. dumping of vehicles – Plate 6 of this report). It does not contain a well-developed area of mangroves, although there are a few individual mangroves scattered along the shoreline there. Given that the Caboolture River is quite deep adjacent to the proposed entrance, dredging should not extend far into the river from the river bank. On balance, impacts associated with disturbance to the river bank are considered small. Moreover, the new shoreline containing the locks would provide some habitat in place of that to be lost.

The capital dredging proposed for the navigation in the lower river is more substantial and would require ongoing maintenance dredging. Invertebrates are likely to recolonise the dredged areas relatively rapidly (e.g. a few months). And, given the long period over which dredging would occur, much of the channel would either be undisturbed or recolonised at any one time. An important part of management would be to monitor recolonisation in terms of the types of assemblages occurring and rates of recolonisation. This information would then be available to understand the impacts of maintenance dredging and to help in refining the ongoing dredging programs.

In additional to monitoring recolonisation, a precautionary approach warrants that further consideration and monitoring be given to the protection of flats adjacent to the navigational channel in the lower river. These flats are of high environmental value and their ecological attributes should be given a high priority in environmental management.

Spoil obtained during capital dredging would be disposed onto the project site, with treatment of spoil for acid soils, as needed. The pipeline to the site would be along the Farry Road easement, but there may be a need to make some slight adjustments to the route (particularly where it passes onto the land) to minimise impacts to wetland habitat. Disposal of spoil obtained from maintenance dredging would initially be onto the project site and later by sale or deposition onto a parcel of land purchased specifically to hold the spoil. Whichever approach is used will require an assessment and management plan to minimise impacts of the longer-term disposal.

5.5.5.5 Altered Tidal Conditions

Modelling described in the EIS indicates that neither the proposed marina basin nor the capital dredging would affect tidal conditions in the Caboolture River. As noted above, the marina basin itself would have little or no tidal range, which has implications for the ecology of the basin (Section 5.5.5.3).

5.5.5.6 Marine Mammals and Marine Reptiles

Apart from dolphins, the likely occurrence of other marina mammals and marine reptiles in the Caboolture River is very small. Dolphins may occur in the river, but speed restrictions for vessels should address issues of potential boat strike. Occurrence of dugong in the river and Deception Bay is also likely to be small, given the general absence in the area of the species of seagrasses on which they feed. Hence, there is a low risk of effects from the proposed development on these marine animals.

The concentration of vessels berthed in the marina basin provides an opportunity to place signs along the catwalks and entrance ways advising of the importance of adhering to speed limits, where the speed limits apply and the need to watch for any marine mammals or marine reptiles at all times which boating.

5.5.5.7 Moreton Bay Marine Park

The Moreton bay marine Park (MBMP) extends into the Caboolture River upstream to the eastern boundary of the NEBP project site. Thus, there would be no direct impacts on the MBMP from activities at the project site. The park does extend along the navigational channel in the lower portion of the Caboolture River and hence would be subject to potential impacts from dredging there.

It is inevitable that, in order to improve navigation within the Caboolture River, there will be some impact on aquatic habitats and biota and hence on the MBMP. As discussed above, impacts could be understood better by monitoring recolonisation after dredging. Further, more detailed modelling of sedimentary processes is recommended to acquire a better understanding of the effects of dredging on adjacent sand flats in the river.

5.5.5.8 Movements of Aquatic Species

The movement of aquatic species in the Caboolture River is currently interrupted by the Caboolture Weir, some 19 km upstream of the river mouth. This barrier isolates a far greater area of aquatic habitat that would otherwise be available to many species, including for example mullet (several species in the family Mugilidae), Australian bass (*Macquaria novemaculeata*), freshwater eels (Family Anguillidae) and several species of commercially important prawns (Family Penaeidae), Below the weir potential movement within the estuary is uninterrupted and this would not change significantly as a result of the proposed development.

Within the marina basin, movement of aquatic species would be via the pumping system and the lock. The design of the pumping system will determine the rate of water exchange (hence opportunities for movement by aquatic species) and the size of aquatic species that can move into the basin. It is likely that in some cases only propagules will be able to pass into the basin via the pumping system. Passage via the lock would be opportunistic but it would be expected that there would be numerous openings on any day/night.

Tidal creeks on the project site are not proposed to be altered. The crossing of Raff Creek should be designed to provide for movement of aquatic species. Similarly, the emplacement of flood mitigation embankments should be designed to cause minimal or no decrease in access to the wetlands for aquatic species. These measures should all be achievable, but would require consideration during the detailed design stage of the project.

6.0 ENVIRONMENTAL MANAGEMENT AND MONITORING

6.1 General Approach

A precautionary approach to the proposed Northeast Business Park development at Caboolture requires the design and implementation of management plan for matters related to aquatic ecology and maintenance or improvement of aquatic environmental values. The following core components for this management are as follow:

5. Design of safeguards for various activities and to cover unforeseen events, such as spillages.
6. Development of key performance indicators (PIs) against which safeguards can be measured.
7. Development of audits or monitoring programs to measure the PIs.
8. Feedback mechanisms to ensure that corrective action is initiated appropriately and within an appropriate time frame.
9. Reporting mechanisms to provide regular reports on environmental management and, where necessary, specific reports on responses to problems as they arise and are dealt with. These reports should be available –preferably via a Web page - to shareholders and all relevant stakeholders, including the community and regulatory authorities.

The EIS provides a basis for comprehensive environmental management through the design, construction and operational phases of the project (Cardno 2007a). In particular, specialist advice on acid soils outlines procedures for identifying and treating acid sulphate soils on site and transported to the site from the dredging of the lower river. The SBMP for the marina incorporates a range of ERAs and management of those and it would also incorporate monitoring of the ecological health of the aquatic environment of the basin.

PIs for some components of water quality are readily available as water quality guidelines. The Healthy Waterways Strategy 2007 – 2012 provides water quality objectives to protect the aquatic ecosystem specific to the Caboolture River (Healthy Waterways 2007a). These apply to the lower, mid- and upper estuary and include nutrients, dissolved oxygen, turbidity, chlorophyll-a, Secchi depth, suspended solids and pH. Some of the other typical indicators, such as contaminants of concern (e.g. some metals, oil and grease, pesticides) can be based in the ANZECC (2000) water quality guidelines.

Other components of water quality and numerous ecological indicators do not have PIs readily available as guidelines. For example, as far as is known, there are no accepted guidelines applicable in Australia for iron and aluminium in estuarine waters.

Additionally, it is difficult to specify PIs for biodiversity as assemblages of biota are highly variable in space and time due to natural causes. Here PIs should be developed around comparisons of field data to background conditions and, where available, to control locations. These are often collectively known as the "ecological baseline". PIs that under-perform or exceed the ecological baseline can be evaluated against a precautionary approach and the consequences of management action or inaction can be determined. Given the lead time available prior to commencement of works, it is highly advisable that an ecological baseline of data is acquired as soon as practicable. The data collected for this report provides some of the data for the baseline, but is not in itself sufficient as the baseline. It may also be possible to link PIs for the project to ongoing ecological studies, for example the work being done as part of the Healthy Waterways strategy.

PIs would be measured by audit and/or ecological monitoring. Audits generally apply at the systems level and ensure that management strategies are sufficient to deal with their stated objectives, that measures of quality assurance (QA) have been developed and that they are being adhered-to.

Monitoring generally applies to the acquisition, analysis and interpretation of data on the environment. Current best practice in ecological monitoring usually entails a "BACI" (Before-After-Control-Impact) approach. This requires replicated quantitative sampling on multiple occasions before and after (and, if appropriate during) the period(s) of environmental disturbance at the site of disturbance and at multiple control sites. The before and Control components of the monitoring represent and measure natural variability, which is compared to the After and Impact components which provide and measure the magnitude of changes in the PI being measured. There is a range of statistical procedures available to provide an objective test of the hypothesis that an impact has occurred, some of which (e.g. ANOVA, ANOSIM) have been used in this report.

Feedback mechanisms are essential to ensure that management responds to impacts to the aquatic environment that have been detected either from monitoring of perhaps following mishaps (e.g. a spillage). Feedback should be developed well in advance and include allocation of specific tasks to specific job roles.

Finally, reports should be prepared to provide the results of monitoring and management responses, both on a regular basis and following any mishaps that need responsive action. These reports should provide a non-technical summary and well as data and analysis and interpretation. They should also be available –preferably via a Web page - to shareholders and all relevant stakeholders, including the community and regulatory authorities.

The next two sections provide a overview of the types of management and monitoring that should be considered in terms of aquatic ecology during construction and operation. This overview is not comprehensive as further items may emerge during detailed design and following discussions with regulatory authorities.

6.2 Environmental Management During Construction

- Ecological health of the Caboolture River
    - Continue regular water quality sampling in Caboolture River from weir to river mouth
    - Establish linkages with Healthy Waterways Program and Caboolture Council in terms of:
        - Waterways sampling programs
        - Lyngbya monitoring and clean-ups
- River Foreshore
    - River bank and river bed adjacent to lock – benthos; fish; water and sediment quality

- Sample potential impact sites and at controls upstream and downstream of marina entrance

- Marina Basin
  - No pre-construction baseline available because the site is currently largely terrestrial with a small amount of estuarine wetland.
  - Water quality discharges
- On-site Wetlands – Conservation and Restoration
  - Establish monitoring sites for assessment construction of flood mitigation embankments
  - Map route for wetland walkway and collect data on flora and fauna
  - Select control locations on the project site and in other wetlands of the Caboolture River
  - Survey wetlands in detail to determine areas suitable for restoration
  - Measure tidal penetration
  - Survey fish and invertebrates
  - Develop management plan for restorative works
- Capital Dredging
  - Set up permanent sites for monitoring flats and channel habitats
  - Establish sites for monitoring recolonisation of benthic invertebrates and undertake sampling before and after dredging of selected areas.
  - Investigate and, if feasible, establish control locations in two other estuaries.
  - Determine environmental value of pipeline route for slurry from Caboolture River to project site. Implement mitigative measures and/or monitoring as required.

6.3 Environmental Management During Operation

- River Foreshore
  - Establish monitoring sites for measuring changes in bank erosion
  - Establish baseline and monitor benthic invertebrates at selected sites subject to erosion before and after commencement of commissioning of the marina.
- Marina Basin and Vessel Movements
  - Develop and implement a strategy to enhance habitats of the basin, including creation of habitat along the eastern foreshore.
  - Measure performance of pumping system to maintain water quality in the basin.
  - Establish monitoring sites for water quality, sediment quality, fish and invertebrates in the marina basin and adjacent river.

- Commence sampling once the basin is filled and during various stages of development. This is likely to be necessary on an ongoing basis through the life of the project, but with scope to vary the frequency depending on achieving PIs.

- On-site Wetlands – Conservation and Restoration
  - Continue sampling in locations selected for walkway, restoration of degraded habitat and any areas that may be affected by the flood mitigation embankments.

- Maintenance Dredging
  - Adapt monitoring of capital dredging to the ongoing maintenance dredging
  - Include sampling of navigational channel and adjacent flats.
  - Include sampling of fish (e.g. by seining) in channel and on flats.

6.0 STUDY TEAM

This report was prepared by Dr Marcus Lincoln-Smith with assistance from Dr Craig Blount and Dr Arthur Dye. Field work was done by Marcus Lincoln-Smith, Joe Neilson, Marcus Schnell and Tony Heugh & Sheeba. Jeff Smith and Robin Mudie of NEBP Pty Ltd have provided assistance with project co-ordination, acquiring data and reports, and assisting with transport and access to the project site.

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TABLES

Table 1. Report Card Grades for estuaries derived from Ecosystem Health Index (EHI) developed as part of the Southeast Queensland Regional Water Quality Management Strategy. A = excellent, B = good, C = fair, D = poor, F = fail, - = no grade given or grading could not be found. Source: Healthy Waterways website (www.healthywaterways.org).

Estuary	Year of assessment							
	2007	2006	2005	2004	2003	2002	2001	2000
Noosa River	A	A-	A	A-	B+	A-	A-	A-
Maroochy River	C-	D+	C	D	D+	C	C	C+
Mooloolah River	B	B	B	B-	B-	B	B-	B
Pummicestone Passage	C-	B	C+	B-	B-	A-	B	B-
Caboolture River	**D**	**D**	**D+**	**C-**	**C-**	**C**	**C**	**C**
Pine Rivers	C-	D	D	D+	D+	D+	D+	D
Cabbage Tree Creek	F	D-	D-	D-	-	-	-	-
Tingalpa Creek	D+	D	D	D-	-	-	-	-
Brisbane River	D+	D-	D-	D-	D-	D-	D-	D
Oxley Creek	F	F	F	F	-	-	-	-
Logan River	D-	F	D-	D	D-	D-	D-	D
Bremer River	F	F	F	F	F	F	F	F
Albert River	F	F	F	F	F	D	D	D
Pimpana River	C+	C	C	C	C-	-	-	-
Coomera River	B	A-	B+	B	B	B	B	B+
Nerang River	B	B	B	B	B-	B	B	C+
Tallebudgera Creek	B-	B+	A-	A-	B	-	-	-
Currimbin Creek	B-	A-	A-	A-	B+	-	-	-
Erapah Creek	D	C-	-	-	-	-	-	-
Tweed River	-	-	-	-	-	-	B-	C+

Table 2. List of scheduled marine species and populations and Ramsar sites listed under the *Nature Conservation* (NC) Act and the *Environment Protection and Biodiversity Conservation* (EPBC) Act where species or species habitat may occur within the vicinity of the proposed development. E = endangered, CE = critically endangered, V = vulnerable, R = rare and M = migratory.

Scheduled Species	Common name	Habitat	Status under *NC Act*	Status under *EPBC Act*
Fish				
Pseudomugil mellis	Honey blue-eye	Freshwater, brackish waterways	V	V
Carcharius taurus	Grey nurse shark (east coast population)	Marine, estuaries	E	CE
Carcharodon carcharias	Great white shark	Marine, estuaries		V, M
Marine Mammals				
Dugong dugon	Dugong	Marine, estuaries	V	M
Orcaella brevirostris	Irrawaddy river dolphin	Marine, estuaries	R	M
Sousa chinensis	Indo-Pacific humpback dolphin	Marine, estuaries	R	M
Marine Reptiles				
Caretta caretta	Loggerhead turtle	Marine, estuaries	E	E, M
Chelonia mydas	Green turtle	Marine, estuaries	V	V, M
Dermochelys coriacea	Leathery, leatherback, luth turtle	Marine, estuaries	E	V, M
Lepidochelys olivacea	Pacific ridley, olive ridley	Marine, estuaries	E	E, M
Eretmochelys imbricata	Hawksbill turtle	Marine, estuaries	V	V
Birds				
Haliaeetus leucogaster	White-bellied sea-eagle	Marine, estuaries		M
Calidris ferruginea	Curlew sandpiper	Beaches, mudflats, mangroves		M
Charadrius mongolus	Lesser sand plover, Mongolian plover	Beaches, mudflats, & mangroves		M
Gallinago hardwickii	Latham' snipe	Wetlands, beaches, mudflats		M
Heteroscelus brevipes	Grey-tailed tattler	Beaches, mudflats		M
Limosa lapponica	Bar-tailed godwit	Beaches, mudflats, mangroves		M
Numenius madagascariensis	Eastern curlew	Beaches, mudflats, mangroves	R	M
Esacus neglectus	Beach stone-curlew	Beaches, mudflats	V	
Numenius phaeopus	Whimbrel	Beaches, mudflats, mangroves		M
Xenus cinereus	Terek sandpiper	Beaches, mudflats, mangroves		M
Ramsar Sites				
Moreton Bay				P

Table 3. Water quality measured in the Caboolture River using a probe, 19 March 2005. Stippled values are outside ANZECC Water Quality Guidelines. Superceded numbering code for sites shown in brackets. Note: 1) pH was not measured due to a faulty sensor; 2) the site originally sampled as Site 1 (designated here as Site 13a) was subsequently superceded by Site 14, further downstream; and 3) Sites 8, 9 & 10 were sampled twice during the same day.

Sampling Site	Time	Easting (WGS 84)	Northing (WGS 84)	Depth m (surface & bottom)	Rep.	Temp C	Salinity ppt	ORP mv	DO%	DO mg/L	Turbidity ntu
				ANZECC:	-	-			80-110	-	0.5 - 10
9 (5)	1020	500918	7001175	0	1	26.85	27.41	625	103.2	7.0	13.0
				0	2	26.93	27.34	626	104.8	7.1	4.3
				2.5	1	26.54	30.40	624	86.4	5.8	10.9
				3.2	2	26.61	30.03	627	86.3	5.8	11.1
10 (4)	1040	500918	7001175	0	1	26.95	28.49	628	103.2	7.0	13.0
				0	2	26.87	28.37	627	102.3	7.0	8.3
				3.3	1	26.56	30.84	627	88.0	5.9	8.0
				6.0	2	26.62	31.61	628	83.4	5.6	9.8
8 (6)	1100	500238	7001056	0	1	27.13	26.37	629	104.5	7.1	6.4
				0	2	27.10	26.39	628	104.0	7.1	7.3
				4.5	1	26.71	31.01	628	82.3	5.5	13.4
				4.5	2	26.68	30.88	627	79.3	5.3	14.8
7 (7)	1130	500614	7002148	0	1	27.43	20.92	628	119.4	8.4	2.2
				0	2	27.47	21.02	627	116.4	8.2	5.2
				3.0	1	26.73	24.79	628	89.4	6.3	12.9
				2.6	2	27.75	24.76	627	91.6	6.4	11.8
3 (8)	1140	499822	7002307	0	1	27.74	12.54	629	124.1	9.1	10.8
				0	2	28.16	12.76	627	121.9	8.9	11.8
				2.8	1	27.07	16.52	628	74.2	5.3	64.1
				2.0	2	27.04	16.93	626	74.3	5.2	40.3
1 (9)	1230	495835	7003962	0	1	28.86	12.99	631	125.0	9.0	5.4
				0	2	28.74	12.97	628	120.8	8.8	10.1
				1.5	1	27.16	13.22	630	32.4	2.2	24.7
				1.6	2	27.74	13.00	626	34.9	2.6	21.0
8 (6)	1400 Time 2	500250	7001086	0	1	28.31	25.81	626	141.6	9.5	30.6
				0	2	28.11	26.02	617	132.9	9.0	18.8
				4.8	1	26.71	30.14	622	94.7	6.5	47.6
				5.0	2	26.67	29.83	614	89.7	6.1	31.3
9 (5)	1415 Time 2	500879	7000721	0	1	28.08	27.62	609	127.7	8.6	2.8
				0	2	28.08	27.64	608	127.2	8.6	6.4
				3.4	1	26.64	30.39	608	94.4	6.3	14.1
				2.6	2	26.66	30.09	608	95.1	6.4	8.1
10 (4)	1430 Time 2	500889	7001181	0	1	28.02	28.76	607	123.3	8.3	4.0
				0	2	28.09	28.72	608	122.1	8.2	5.5
				3.4	1	26.52	31.72	607	90.8	6.1	14.6
				2.6	2	26.58	30.19	608	99.5	6.5	9.4
11 (3)	1440	501567	7001570	0	1	28.14	30.15	610	128.1	8.5	0.2
				0	2	28.11	30.26	610	123.4	8.2	4.6
				3.5	1	26.63	31.76	611	108.5	7.3	9.2
				3.0	2	27.22	30.58	611	115.3	7.7	7.6
13 (2)	1455	503471	6999154	0	1	27.60	33.89	613	117.9	7.6	5.3
				0	2	27.41	34.14	612	109.5	7.2	10.8
				1.6	1	27.40	33.89	613	115.3	7.5	13.0
				2.0	2	27.35	34.02	612	110.0	7.2	8.4
13a (1)	1510	503409	6997256	0	1	26.79	35.36	612	115.3	7.5	3.9
				0	2	26.74	34.50	611	116.7	7.7	3.9
				3.0	1	26.43	35.78	610	107.3	7.1	5.6
				3.0	2	26.57	35.81	610	112.4	7.5	2.7

Table 4. Water quality measured in the Caboolture River using a probe, 12 December 2005. Stippled values are outside ANZECC Water Quality Guidelines.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	**-**	**-**	**7.0-8.5**		**80-110**	**-**	**0.5 - 10**
1	07:15	495836	7003965	1	0.0	29.03	0.15	7.08	348	58.9	4.6	22.6
				2	0.0	29.00	0.15	7.07	333	59.0	4.5	47.2
				1	2.8	28.45	0.12	7.12	337	63.1	4.9	71.5
				2	2.9	28.78	0.13	7.10	320	60.0	4.6	48.2
2	07:40	496888	7003064	1	0.0	29.37	0.33	6.90	309	27.4	2.1	37.7
				2	0.0	29.41	0.34	6.94	267	27.7	2.1	47.1
				1	3.1	29.34	0.33	6.91	286	26.9	2.1	49.6
				2	3.0	29.39	0.33	6.91	243	26.5	2.0	52.9
3	08:00	497608	7003626	1	0.0	29.70	0.46	6.89	325	25.2	1.9	44.0
				2	0.0	29.70	0.46	6.91	293	25.3	1.9	48.9
				1	3.4	29.68	0.44	6.89	308	24.9	1.9	48.2
				2	3.4	29.70	0.46	6.89	264	24.8	1.9	56.3
4	08:20	498093	7002959	1	0.0	29.66	0.66	6.86	357	25.7	2.0	45.0
				2	0.0	29.67	0.70	6.94	291	26.7	2.0	46.3
				1	3.0	29.76	0.77	6.85	314	24.4	1.8	46.5
				2	4.1	29.73	0.75	6.87	276	25.2	1.9	49.7
5	08:30	498932	7002527	1	0.0	29.76	1.52	6.75	266	24.6	1.9	42.2
				2	0.0	29.76	1.32	6.85	218	26.4	2.0	48.2
				1	4.2	29.78	1.62	6.74	242	23.6	1.8	45.5
				2	4.1	29.78	1.53	6.76	186	23.6	1.8	59.1
6	08:55	499895	7002057	1	0.0	29.76	3.74	6.66	216	27.8	2.1	32.2
				2	0.0	29.74	3.82	6.70	140	27.3	2.0	48.0
				1	5.2	29.90	5.72	6.68	141	28.9	2.1	48.3
				2	3.9	29.89	5.62	6.67	136	28.8	2.1	51.1
7	09:12	500612	7002158	1	0.0	29.90	7.30	6.70	232	36.0	2.6	38.1
				2	0.0	29.93	7.44	6.76	174	36.2	2.6	39.6
				1	4.0	30.07	9.40	6.75	186	39.7	2.8	39.7
				2	4.2	30.06	8.93	6.78	157	39.8	2.9	42.6
8	09:25	500268	7001082	1	0.0	29.73	14.11	7.02	298	53.5	3.6	33.6
				2	0.0	30.06	13.70	7.04	251	55.4	3.9	42.5
				1	4.7	30.16	14.17	7.05	262	55.1	3.8	53.9
				2	4.5	30.16	14.22	7.06	234	55.9	3.9	55.6
9	09:40	500878	7000752	1	0.0	30.08	14.48	7.03	258	57.4	4.0	40.9
				2	0.0	30.09	14.45	7.08	225	57.7	4.0	40.7
				1	3.0	30.07	14.88	7.08	235	55.3	3.8	53.7
				2	3.2	30.07	14.97	7.08	210	55.7	3.9	54.0
10	09:50	500825	7001155	1	0.0	29.99	14.97	7.09	176	56.8	4.0	43.4
				2	0.0	29.99	15.04	7.11	170	57.5	4.0	43.3
				1	4.1	29.97	15.22	7.11	172	56.9	4.0	45.8
				2	5.6	30.00	14.96	7.10	169	57.3	4.0	48.4
11	10:05	501444	7001602	1	0.0	29.73	16.64	7.07	246	59.3	4.1	39.8
		501614	7001565	2	0.0	29.68	16.73	7.24	232	59.3	4.1	39.5
				1	5.6	29.63	18.83	7.30	232	60.1	4.1	46.8
				2	4.2	29.66	18.98	7.31	222	61.1	4.2	47.3

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Table 4, cont.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	**-**	**-**	**7.0-8.5**		**80-110**	**-**	**0.5 - 10**
12	10:20	502168	6999841	1	0.0	29.68	19.00	**4.90**	301	**70.8**	4.9	**31.2**
				2	0.0	29.46	19.00	7.36	186	**66.7**	4.6	**36.4**
				1	4.8	29.50	23.14	**4.84**	155	**68.2**	4.6	**38.8**
				2	4.6	29.24	25.77	7.81	170	**71.2**	4.7	**41.7**
13	10:40	503510	6999069	1	0.0	29.49	21.40	7.63	170	**74.3**	5.0	**30.8**
				2	0.0	29.45	22.35	7.71	166	**76.0**	5.2	**39.4**
				1	1.7	29.27	24.60	7.30	167	**71.7**	4.8	**36.0**
				2	1.8	29.24	25.44	7.86	166	**74.2**	4.9	**43.9**
14	10:55	503355	6997215	1	0.0	29.33	25.99	7.95	148	**83.4**	5.5	**27.0**
				2	0.0	29.40	25.80	7.93	151	**83.7**	5.5	**37.2**
				1	2.3	28.97	27.14	7.95	148	**79.5**	5.2	**34.6**
				2	2.3	28.94	27.46	7.95	151	**80.9**	5.3	**42.8**

Table 5. Water quality measured in the Caboolture River using a probe, 16 January 2006. Stippled values are outside ANZECC Water Quality Guidelines.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	-	-	7.0-8.5		80-110	-	0.5 - 10
1	11:40	495841	7003967	1	0.0	30.42	0.29	8.85	46	300.0	20.0	20.5
				2	0.0	30.55	0.27	8.93	64	300.0	20.0	17.8
				1	3.1	28.54	0.23	7.59	69	82.1	6.4	8.6
				2	3.1	28.54	0.23	7.64	98	92.9	7.1	7.3
2	12:02	496874	7003070	1	0.0	30.25	0.52	7.50	125	101.4	7.9	26.6
				2	0.0	30.19	0.52	7.49	141	102.3	7.7	26.2
				1	3.6	29.07	0.47	7.40	124	74.3	5.8	28.7
				2	3.5	29.04	0.47	7.39	133	73.5	5.7	28.5
3	12:26	497551	7003575	1	0.0	30.62	0.65	7.57	146	115.9	8.6	32.9
				2	0.0	31.28	0.66	7.60	141	125.6	9.3	31.2
				1	4.5	29.54	0.70	7.41	137	82.2	6.3	63.5
				2	4.5	29.55	0.68	7.41	120	83.6	6.4	44.4
4	12:50	498092	7002950	1	0.0	31.25	0.86	7.70	123	139.2	10.2	37.2
				2	0.0	31.42	0.85	7.64	122	132.1	9.7	36.5
				1	2.9	29.70	1.18	7.37	124	83.2	6.3	54.0
				2	3.3	29.67	1.16	7.36	122	82.3	6.2	52.3
5	13:20	498923	7002512	1	0.0	30.16	1.74	7.35	119	95.7	7.2	47.3
				2	0.0	30.32	1.68	7.44	141	98.7	7.0	44.0
				1	3.9	29.72	2.01	7.24	116	74.1	5.5	65.2
				2	3.9	29.84	1.94	7.25	141	77.7	5.8	64.9
6	14:05	499967	7002167	1	0.0	30.18	3.65	7.28	77	106.8	7.9	51.2
				2	0.0	30.25	3.51	7.27	130	98.9	7.4	50.1
				1	2.4	29.85	4.26	7.20	77	82.8	6.1	74.6
				2	3.4	29.76	5.28	7.18	116	81.0	5.9	94.6
7	14:30	500601	7002159	1	0.0	30.41	5.97	7.33	76	110.1	8.1	52.6
				2	0.0	30.21	6.13	7.31	94	99.1	7.3	57.4
				1	4.6	29.94	8.36	7.28	71	92.4	6.7	68.9
				2	3.1	30.01	6.86	7.27	85	94.9	6.9	67.3
8	14:50	500262	7001068	1	0.0	30.41	13.15	7.54	54	111.8	7.8	20.4
				2	0.0	30.40	13.04	7.55	65	111.9	7.8	20.0
				1	5.1	30.23	14.48	7.52	47	98.4	6.9	50.0
				2	5.0	30.22	14.24	7.52	57	99.2	6.9	91.7
9	15:05	500863	7000754	1	0.0	30.46	14.06	7.63	46	114.0	7.9	13.5
				2	0.0	30.42	14.05	7.60	63	106.5	7.3	15.0
				1	2.8	30.24	15.09	7.56	41	100.5	7.0	124.7
				2	2.9	30.24	15.05	7.56	55	101.1	7.0	95.8
10	15:16	500850	7001159	1	0.0	30.22	15.64	7.60	55	102.3	7.1	53.7
				2	0.0	30.27	15.52	7.60	71	104.6	7.3	43.1
				1	4.8	30.23	15.62	7.60	51	102.8	7.1	67.4
				2	6.2	30.24	15.53	7.60	64	99.8	6.9	77.5
11	15:30	501574	7001581	1	0.0	29.95	17.27	7.70	55	108.0	7.4	18.6
				2	0.0	30.50	17.18	7.68	57	107.5	7.4	18.3
				1	4.4	29.63	18.18	7.68	41	97.1	6.7	62.7
				2	4.7	29.81	17.43	7.66	53	98.8	6.8	44.5

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Table 5, cont.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
12	15:48	502170	6999761	1	0.0	29.99	18.18	7.75	47	**115.6**	8.0	**13.7**
		502216	6999759	2	0.0	29.92	18.45	7.76	120	**116.0**	8.0	**18.0**
				1	2.9	29.51	19.42	7.90	34	**113.3**	7.5	**43.5**
				2	3.9	29.11	23.44	7.94	92	102.0	6.9	**24.4**
13	16:07	503469	6999221	1	0.0	29.82	22.23	7.99	33	**120.0**	8.1	**22.7**
				2	0.0	29.80	21.76	7.98	44	**126.0**	8.4	**21.7**
				1	0.9	29.82	22.17	7.99	32	**123.5**	8.3	**24.2**
				2	0.8	29.80	21.66	7.98	39	**124.9**	8.4	**25.6**
14	16:27	503439	6997102	1	0.0	29.96	25.20	8.11	26	**132.2**	8.6	**18.5**
				2	0.0	29.97	25.16	8.11	37	**126.2**	8.3	**16.1**
				1	2.3	30.03	25.74	8.11	25	**127.0**	8.3	**30.2**
				2	2.2	30.06	25.78	8.12	33	**126.0**	8.3	**26.4**

Table 6. Water quality measured in the Caboolture River using a probe, 25 & 26 April 2006. Stippled values are outside ANZECC Water Quality Guidelines.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	**-**	**-**	**7.0-8.5**		**80-110**	**-**	**0.5 - 10**
1	11:25	495865	7003959	1	0.0	24.17	8.31	7.15	569.00	58.6	4.7	6.87
				2	0.0	24.06	8.36	7.19	569	58.1	4.7	7.00
				1	1.5	23.69	8.33	7.14	573	47.4	3.8	7.33
				2	1.5	23.61	8.29	7.13	538	47.9	4.0	8.70
2	11:55	496900	7003062	1	0.0	23.76	8.58	7.27	524	70.2	5.6	7.67
				2	0.0	23.78	8.60	7.27	537	68.5	5.5	10.17
				1	2.3	23.47	9.29	7.22	534	58.7	4.6	10.90
				2	2.9	23.44	9.00	7.23	541	58.7	4.7	11.40
3	12:17	497539	7003586	1	0.0	23.94	9.07	7.30	528	70.7	5.7	9.13
				2	0.0	24.05	9.00	7.30	535	68.6	5.5	9.57
				1	3.5	23.59	11.14	7.29	537	58.8	4.7	21.17
				2	3.3	23.54	10.69	7.27	541	59.6	4.7	16.17
4	12:35	498090	7002942	1	0.0	23.99	9.99	7.36	527	74.6	5.9	14.20
				2	0.0	24.03	9.92	7.37	533	73.3	5.8	13.10
				1	3.2	23.61	11.34	7.32	532	63.1	5.0	22.23
				2	3.2	23.60	11.39	7.32	537	61.5	4.9	22.33
5	14:10	498938	7002531	1	0.0	24.06	10.57	7.47	521	73.7	5.8	18.60
				2	0.0	24.05	10.57	7.45	526	73.9	5.8	16.87
				1	2.9	24.03	10.66	7.46	526	72.9	5.8	17.93
				2	3.0	23.97	10.78	7.43	530	70.6	5.6	19.30
6	15:05	499882	7002044	1	0.0	24.03	12.19	7.57	479	80.9	6.3	20.10
				2	0.0	23.99	12.06	7.58	496	81.1	6.4	15.57
				1	3.9	24.02	12.41	7.54	494	77.7	6.0	32.00
				2	3.9	24.02	12.41	7.53	501	75.6	5.9	35.40
7	14:40	500617	7002186	1	0.0	23.69	14.92	7.73	507	84.0	6.5	25.87
				2	0.0	23.71	14.83	7.74	512	82.4	6.4	22.63
				1	1.7	23.68	14.93	7.73	511	83.2	6.5	30.80
				2	2.1	23.68	14.90	7.73	515	81.4	6.4	31.03
8	15:00	500251	7001028	1	0.0	23.73	18.93	7.73	514	81.2	6.1	27.83
				2	0.0	23.82	18.84	7.69	512	78.9	6.0	26.40
				1	4.5	23.79	19.22	7.70	513	78.6	5.9	59.97
				2	5.1	23.76	19.39	7.67	515	79.7	5.7	38.70
9	15:55	500850	7000731	1	0.0	23.83	19.21	7.76	510	83.3	6.3	19.20
				2	0.0	23.83	19.18	7.78	516	84.6	6.4	17.83
				1	2.0	23.83	19.57	7.71	516	77.2	5.9	23.47
				2	2.1	23.80	19.75	7.66	484	76.2	5.7	26.73
10	17:20	500836	7001164	1	0.0	23.93	22.41	7.76	504	79.9	5.7	23.40
				2	0.0	23.83	22.59	7.77	513	76.1	5.6	23.97
				1	4.1	23.97	22.72	7.79	510	74.9	5.4	32.70
				2	4.1	23.88	22.90	7.75	516	73.9	5.4	36.20
11	11:35	501613	7001587	1	0.0	23.21	27.90	7.07	502	69.7	5.0	21.50
				2	0.0	23.23	27.79	7.87	503	71.3	5.2	16.90
				1	5.7	22.94	28.30	7.89	506	69.8	5.1	33.50
				2	5.6	22.97	28.26	7.08	506	69.7	5.1	31.07

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Table 6 cont.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep.	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	**-**	**-**	**7.0-8.5**		**80-110**	**-**	**0.5 - 10**
12	10:20	502166	6999843	1	0.0	22.03	32.10	8.04	488	**71.1**	5.1	**13.97**
				2	0.0	22.07	31.99	8.06	489	**72.5**	5.3	**12.53**
				1	5.7	21.91	32.19	8.07	489	**73.4**	5.3	**15.10**
				2	5.7	21.96	32.10	8.08	489	**72.6**	5.3	**16.93**
13	09:20	503491	6999171	1	0.0	21.44	34.51	8.21	493	**76.2**	5.5	8.53
				2	0.0	21.43	34.49	8.23	490	**76.9**	5.5	7.60
				1	2.2	21.36	34.50	8.23	492	**77.8**	5.6	9.30
				2	2.3	21.37	34.57	8.24	490	**77.8**	5.6	9.20
14	08:20	503358	6997231	1	0.0	21.43	34.60	8.22	567	81.1	5.9	**11.67**
				2	0.0	21.48	34.71	8.16	530	**78.5**	5.6	**12.23**
				1	3.5	21.33	34.76	8.23	557	**76.4**	5.5	**11.10**
				2	3.5	21.39	34.74	8.20	528	**77.3**	5.6	**10.60**

Table 7. Water quality measured in the Caboolture River using a probe, 21 August, 2006. Stippled values are outside ANZECC Water Quality Guidelines.

Site Number	Time	Easting (WGS 84)	Northing (WGS 84)	Rep	Depth m (surface & bottom)	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
					ANZECC:	**-**	**-**	**7.0-8.5**		**80-110**	**-**	**0.5 - 10**
1	09:25	495839	7003958	1	0.0	16.92	15.87	7.15	431	**53.1**	4.7	0.7
				2	0.0	17.03	15.89	7.10	422	**53.0**	4.6	**0.0**
				1	2.1	16.92	15.91	7.13	425	**50.0**	4.4	1.6
				2	2.0	16.95	15.93	7.10	415	**51.6**	4.5	2.1
2	09:50	496886	7003066	1	0.0	17.04	16.71	7.19	421	**67.0**	5.9	4.2
				2	0.0	16.99	16.24	7.18	419	**66.4**	5.8	4.2
				1	1.9	17.01	17.26	7.19	421	**64.1**	5.6	8.3
				2	2.4	17.01	17.09	7.19	419	**64.4**	5.7	4.3
3	10:05	497547	7003589	1	0.0	17.21	17.02	7.21	421	**71.6**	6.2	3.8
				2	0.0	17.16	17.29	7.22	423	**72.1**	6.3	3.2
				1	3.4	16.92	18.02	7.24	423	**66.4**	5.8	**10.8**
				2	2.8	16.93	17.81	7.24	424	**67.5**	5.8	6.2
4	10:20	498086	7002939	1	0.0	17.03	18.35	7.27	423	**72.3**	6.2	6.2
				2	0.0	17.01	18.31	7.27	425	**73.0**	6.3	6.0
				1	3.0	16.87	18.87	7.27	424	**68.9**	6.0	**10.8**
				2	2.6	16.87	18.80	7.27	427	**68.9**	6.0	**10.0**
5	10:28	498911	7002505	1	0.0	16.97	19.44	7.29	427	**73.8**	6.3	9.3
				2	0.0	16.96	19.44	7.29	429	**73.5**	6.3	**11.4**
				1	2.7	16.89	19.76	7.29	428	**71.6**	6.1	10.0
				2	2.9	16.89	19.75	7.29	430	**72.8**	6.2	**12.8**
6	10:45	499886	7002044	1	0.0	17.01	22.28	7.31	424	**73.4**	6.2	3.4
				2	0.0	17.03	22.23	7.31	425	**73.5**	6.2	3.4
				1	4.3	16.89	23.15	7.30	425	**69.2**	5.9	8.8
				2	4.5	16.90	23.04	7.30	426	**70.0**	5.9	8.5
7	10:55	500609	7002154	1	0.0	17.04	24.76	7.30	423	**70.0**	5.8	5.0
				2	0.0	17.05	24.72	7.30	424	**69.6**	5.8	4.7
				1	3.6	16.98	25.05	7.30	424	**68.6**	5.7	8.3
				2	3.3	16.98	25.13	7.30	424	**68.2**	5.7	6.9
8	11:20	500266	7001086	1	0.0	17.25	29.43	7.39	425	**74.7**	6.0	6.4
				2	0.0	17.29	29.39	7.38	425	**74.7**	6.0	5.5
				1	4.2	17.15	30.12	7.41	426	**74.1**	6.0	**10.7**
				2	5.4	17.15	30.30	7.41	427	**73.5**	5.9	**10.2**
9	11:25	500854	7000738	1	0.0	17.43	30.35	7.41	428	**77.9**	6.2	5.0
				2	0.0	17.44	30.36	7.41	428	**78.0**	6.2	6.1
				1	2.5	17.21	31.02	7.44	428	**76.2**	6.1	8.1
				2	3.6	17.24	30.67	7.43	421	**77.1**	6.1	6.8
10	11:30	500832	7001134	1	0.0	17.43	31.43	7.46	418	**79.6**	6.3	**11.2**
				2	0.0	17.41	31.33	7.45	420	**79.1**	6.3	7.4
				1	6.3	17.33	31.41	7.47	419	**78.8**	6.3	9.5
				2	6.3	17.34	31.41	7.46	421	**78.7**	6.3	9.6
11	11:40	501538	7001583	1	0.0	17.64	32.74	7.52	425	85.1	6.7	5.3
				2	0.0	17.61	32.74	7.53	425	86.3	6.8	4.9
				1	2.9	17.50	32.99	7.55	425	85.2	6.7	9.8
				2	4.3	17.51	33.16	7.55	426	85.0	6.7	**11.3**
12	11:55	502140	6999899	1	0.0	18.13	34.62	7.63	428	96.5	7.4	3.5
				2	0.0	18.05	34.54	7.64	430	96.4	7.4	3.5
				1	4.1	17.65	35.72	7.74	428	93.3	7.2	7.5
				2	4.5	17.64	35.92	7.74	430	92.9	7.2	8.8
13	12:03	503434	6999217	1	0.0	18.05	36.31	7.76	429	98.4	7.5	3.1
				2	0.0	18.00	36.30	7.75	430	97.9	7.4	4.8
				1	1.0	18.00	36.15	7.76	430	99.6	7.6	4.2
				2	0.8	18.03	36.37	7.76	431	100.3	7.6	6.0
14	12:12	503387	6997132	1	0.0	18.06	37.38	7.85	429	101.7	7.7	1.7
				2	0.0	18.07	37.33	7.85	430	102.2	7.7	1.7
				1	2.4	18.06	37.41	7.85	430	102.6	7.7	1.3
				2	2.4	18.04	37.36	7.85	430	102.7	7.8	1.8

Table 8. Statistical comparison of water quality indicators using a) ANOVA at sites extending from the mouth to the weir of the Caboolture River on 19/3/05. DF = Degrees of Freedom, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's *C* test). Comparison of means b) using SNK tests. Magnitude of means increases from left to right.

a. ANOVA results

Indicator	**Factor:**	Site (Si)	Depth (De)	Si x De	Residual
	DF:	8	1	8	18
Temperature, C (raw*)	MS	0.573	8.762	0.387	0.047
	F -ratio	12.230	187.100	8.260	
	P	R	R	**<0.0001**	
Salinity, ppt (raw*)	MS	252.007	37.864	2.854	0.167
	F -ratio	1506.470	226.340	17.060	
	P	R	R	**<0.0001**	
ORP, Mv (raw)	MS	329.986	12.250	1.500	5.194
	F -ratio	63.530	2.360	0.290	
	P	**<0.0001**	0.142	0.961	
DO,% (raw)	MS	2392.786	14.440	635.098	380.784
	F -ratio	6.280	0.040	1.670	
	P	**<0.0001**	0.848	0.175	
DO, mg/L (raw)	MS	11.254	0.050	3.112	1.605
	F -ratio	7.010	0.030	1.940	
	P	**<0.0001**	0.856	0.116	
Turbidity (ntu)	MS	445.459	117.723	293.911	38.695
	F -ratio	11.510	3.040	7.600	
	P	**<0.0001**	0.098	**<0.0001**	

b. Outcome of SNK Tests

Indicator	Test	SNK Outcome
Temperature	Sites - surface	S1 < S7 = S2 = S8 = S4 = S5 = S3 = S6 < S9
	Sites - bottom	S1 = S3 = S4 = S5 = S6 = S8 = S7 = S2 = S9
Salinity	Sites - surface	S9 = S8 < S7 < S6 < S5 < S4 < S3 < S2 < S1
	Sites - bottom	S9 < S8 < S7 < S6 = S5 = S4 = S3 < S2 < S1
ORP	Sites - Surface & bottom	S4 = S5 = S3 = S1 = S2 < S6 < S7 = S8 = S9
DO%	Sites - Surface & bottom	S9 < S1 = S2 = S3 = S4 =S5 = S6 = S7 = S8
DO mg/L	Sites - Surface & bottom	S9 < S1 = S2 = S3 = S4 =S5 = S6 = S7 = S8
Turbidity	Sites - Surface & bottom	S1 = S2 = S3 = S4 =S5 = S6 = S7 < S8 = S9

Table 9. Statistical comparison of water quality indicators using ANOVA at Sites 8, 9 & 10 in the Caboolture River adjacent to the development site between morning (1020 - 1100) and afternoon (1400 - 1430) on 19/3/05. DF = Degrees of Freedom, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's *C* test).

Indicator	**Factor:**	Site (Si)	Time (Ti)	Depth (De)	Si x Ti	Si x De	Ti x De	Si x Ti x De	Residual
	DF:	2	1	1	2	2	1	2	12
Temperature, C (raw*)	MS	0.0533	1.9953	5.0600	0.0047	0.0048	1.9267	0.0010	0.0031
	F -ratio	17.37	650.63	1650.01	1.53	1.57	628.26	0.34	-
	P	**0.0003**	R	R	0.2551	0.2486	**<0.0001**	0.7214	-
Salinity, ppt (raw*)	MS	4.8036	0.2035	60.7698	0.4259	1.9565	0.2838	0.0167	0.1391
	F -ratio	34.52	1.46	436.73	3.06	14.06	2.04	0.12	-
	P	R	0.2498	R	0.0843	**0.0007**	0.1787	0.8882	-
ORP, Mv (raw)	MS	120.0417	1380.1667	4.1667	75.5417	3.0417	1.5000	0.8750	6.7500
	F -ratio	17.78	204.47	0.62	11.19	0.45	0.22	0.13	-
	P	R	R	0.4473	**0.0018**	0.6476	0.6458	0.8796	-
DO,% (raw)	MS	9.1754	1860.3204	4452.6504	32.3754	77.8079	370.5204	15.5679	8.8479
	F -ratio	1.04	210.26	503.24	3.66	8.79	41.88	1.76	-
	P	R	R	R	0.0574	**0.0045**	**<0.0001**	0.2137	-
DO, Mg/L (raw)	MS	0.0729	8.0504	21.4704	0.2129	0.2929	1.4504	0.0379	0.0304
	F -ratio	2.40	264.67	705.88	7.00	9.63	47.68	1.25	-
	P	R	R	R	**0.0097**	**0.0032**	**<0.0001**	0.3222	-
Turbidity (ntu)	MS	404.7838	221.4338	220.2204	361.7038	38.0329	71.0704	3.0829	24.4588
	F -ratio	16.55	9.05	9.00	14.79	1.55	2.91	0.13	-
	P	R	R	**0.0111**	**0.0006**	0.2509	0.114	0.8827	-

Table 10. Results of ANOVAs examining variation in water quality over time (December 2005 - August 2006) in the Caboolture River. ti = Times, de = Depths (surface and bottom), si = Sites. *n* = 2 replicates per site. DF = Degrees of Freedom, NT = no test, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an asterisk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Site (Si)	Times (Ti)	Depth (De)	Ti x De	Ti x Si	De x Si	Ti x De x Si	Residual
	DF:	13	3	1	3	39	13	39	112
Temperature, °C (raw)*	MS	0.576	2031.828	0.296	7.176	0.469	0.982	0.525	0.007
	F -ratio	0.000	0.000	0.000	13.630	0.890	1.870	75.560	
	P	R	R	R	**<0.001**	0.641	0.066	**<0.001**	
Salinity, ppt (Ln(x+1))*	MS	1.530	25.749	105.027	8.797	0.141	0.275	0.086	0.001
	F -ratio	0.000	0.000	0.000	101.760	1.630	3.180	147.120	
	P	R	R	R	**<0.001**	0.067	**0.003**	**<0.001**	
ORP, Mv (Sqrt x)	MS	5.460	2202.460	100.815	31.911	3.461	1.004	0.987	0.494
	F -ratio	0.000	0.000	0.000	32.310	3.510	1.020	2.000	
	P	R	R	R	**<0.001**	**<0.001**	0.455	**0.002**	
DO,% (raw)	MS	1194.885	36456.899	12895.712	2668.849	963.772	1108.228	903.756	3.990
	F -ratio	0.000	0.000	0.000	2.95	1.07	1.23	226.54	
	P	R	R	R	**0.044**	0.421	0.298	**<0.001**	
DO, mg/L (raw)	MS	4.766	186.152	24.249	15.762	4.116	4.340	3.836	0.020
	F -ratio	0.000	0.000	0.000	4.110	1.070	1.130	193.940	
	P	R	R	R	**0.013**	0.413	0.364	**<0.001**	
pH, (Ln(x+1))*	MS	0.003	0.073	0.092	0.002	0.002	0.004	0.002	0.001
	F -ratio	0.000	0.000	0.000	0.830	1.010	2.040	1.440	
	P	R	NT	R	0.484	0.489	**0.043**	0.071	

Table 11. Results of ANOVAs examining variation in surface water quality in relation to time of day (December 2005) in the Caboolture River. *n* = 2 replicates per site. DF = Degrees of Freedom, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Times (Ti)	Site (Si)	Ti x Si	Residual
	DF:	1	5	5	12
Temperature, °C (raw)*	MS	6.770	0.280	0.170	0.010
	F -ratio	40.410	38.160	23.110	
	P	R	R	**<0.001**	
Salinity, ppt (Sqrt x)*	MS	1.037	9.816	0.192	0.001
	F -ratio	5.390	13452.430	263.720	
	P	R	R	**<0.001**	
ORP, Mv (raw)	MS	74482.042	1737.942	7476.542	375.708
	F -ratio	9.960	4.630	19.900	
	P	R	R	**<0.001**	
DO,% (raw)	MS	743.707	2004.653	252.789	0.685
	F -ratio	2.940	2926.500	369.03	
	P	R	R	**<0.001**	
DO, mg/L (raw)	MS	4.002	9.268	1.146	0.008
	F -ratio	3.490	1235.730	152.760	
	P	R	R	**<0.001**	
pH, (Ln(x+1))	MS	0.041	0.337	0.064	0.003
	F -ratio	0.640	123.250	23.320	
	P	R	R	**<0.001**	

Table 12. Results of ANOVAs examining variation in bottom water quality in relation to time of day (December 2005) in the Caboolture River. *n* = 2 replicates per site. DF = Degrees of Freedom, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Times (Ti)	Site (Si)	Ti x Si	Residual
	DF:	1	2	2	6
Temperature, °C (raw)	MS	0.001	0.020	0.001	0.000
	F -ratio	0.090	12.380	2.780	
	P	0.797	**0.007**	0.140	
Salinity, ppt (raw)	MS	0.484	0.794	0.256	0.273
	F -ratio	1.890	2.910	0.940	
	P	0.303	0.131	0.443	
ORP, Mv (raw)*	MS	736.333	42.750	30.083	6.333
	F -ratio	24.480	6.750	4.750	
	P	**0.039**	**0.029**	0.058	
DO,% (raw)	MS	285.188	21.216	2.318	10.946
	F -ratio	123.060	1.940	0.21	
	P	**0.008**	0.224	0.815	
DO, mg/L (raw)	MS	1.333	0.056	0.041	0.038
	F -ratio	32.650	1.460	1.070	
	P	**0.029**	0.305	0.402	
Turbidity, ntu (Sqrt x)	MS	2.753	3.838	1.705	0.255
	F -ratio	1.610	15.070	6.700	
	P	R	R	**0.030**	

Table 13. Analyses of water samples collected in collected in the Caboolture River and on the NEBP project site. ANZECC guidelines trigger levels to protect 95% of species. Sites 1, 2, 5, 8, 11 & 13 are in the Caboolture River; other sites are tidal channels within NEBP site (see Figure 1). nd = no data available, numbers preceded by "<" signifiy the result was below the reported detection limit. * ANZECC guidelines for Cr III and Cr VI, respectively.

Site No.	Sample No.	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Se	Zn	TP	NH4	TN	NOx	OP	SS	TKN	Chl-a
		ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	ANZECC:	-	-	5.5	27.4 or 4.4*	1.3	-	4.4	0.4	70	-	15	0.030	0.015	0.30	0.015	0.005	0.5 to 10	-	0.005
a. Samples collected December 2005																				
1	1	510	1.90	<0.1	1.5	3.50	1,500	<1	<0.1	1.2	<1	6.30	0.130	0.020	1.10	0.020	0.008	22	1.10	0.039
	2	510	1.90	<0.1	1.3	3.80	1,600	<1	<0.1	1.5	<1	12.00	0.130	0.036	1.00	0.020	0.007	7	0.98	0.053
2	3	600	2.40	<0.1	1.7	3.10	2,100	<1	<0.1	1.5	<1	9.60	0.160	0.091	1.10	0.150	0.028	15	0.95	0.014
	4	520	2.40	<0.1	1.5	2.80	1,900	<1	<0.1	1.7	<1	13.00	0.150	0.092	1.10	0.150	0.029	14	0.95	0.011
5	5	770	3.20	<0.1	2	3.00	2,200	<1	<0.1	1.6	<1	8.80	0.190	0.180	1.10	0.220	0.067	12	0.88	0.003
	6	800	3.00	<0.1	2.5	3.20	2,300	<1	<0.1	2.5	<1	5.90	0.200	0.200	1.10	0.220	0.063	14	0.88	0.003
8	7	420	1.80	<0.1	1.2	3.20	2,200	<1	<0.1	<5	<1	7.00	0.120	0.180	1.00	0.080	0.009	12	0.92	0.007
	8	350	1.80	0.16	<1	3.10	2,000	<1	<0.1	<5	<1	10.00	0.120	0.160	1.10	0.080	0.008	17	1.00	0.004
11	9	230	1.30	<0.1	<1	3.40	1,100	<1	<0.1	<5	<1	5.80	0.100	0.091	0.86	0.050	0.006	11	0.81	0.009
	10	240	1.40	<0.1	<1	5.30	1,200	<1	<0.1	<5	<1	4.10	0.110	0.096	0.87	0.050	0.006	23	0.82	0.009
13	11	350	1.00	<0.1	1.6	3.00	870	<1	<0.1	<5	<1	5.10	0.091	0.009	0.62	<0.01	<0.005	25	0.62	0.009
	12	320	1.10	<0.1	1.2	3.70	830	<1	<0.1	<5	<1	12.00	0.094	0.015	0.63	<0.01	<0.005	25	0.63	0.014
Raff Ck	13	690	1.40	<0.1	<1	1.70	4,100	<1	<0.1	2.9	<1	28.00	0.120	0.150	0.85	0.020	0.130	4	0.83	0.004
	14	340	1.60	<0.1	<1	1.40	2,100	<1	<0.1	<1	<1	4.60	0.130	0.230	1.10	0.070	0.180	28	1.00	0.009
NEBP East	15	160	1.30	<0.1	<1	<1	10,000	<1	<0.1	2.7	<1	<1	0.170	0.120	1.20	0.020	0.130	28	1.10	0.007
NEBP West	16	190	3.30	<0.1	1.6	2.40	2,900	1.2	<0.1	2.6	<1	3.10	1.100	0.750	3.30	<0.01	0.520	18	3.30	0.110
b. Samples collected in January 2006																				
1	1	99	3.7	<0.1	1.00	1.9	930	<1	<0.1	1.6	<1	3.10	0.140	0.007	1.00	<0.01	0.230	22	1.000	0.120
	2	94	3.3	<0.1	5.00	1.5	800	<1	<0.1	1.6	<1	3.40	0.130	0.005	1.00	<0.01	0.023	15	1.000	0.073
2	3	370	4.4	<0.1	6.00	1.4	1,300	<1	<0.1	2.1	<1	3.30	0.130	0.023	0.97	0.180	0.110	18	0.790	0.047
	4	360	4.6	<0.1	5.70	3.2	1,300	<1	<0.1	2.4	<1	270	0.120	0.020	0.98	0.180	0.080	23	0.800	0.037
5	5	800	2.4	<0.1	4.80	2.1	2,100	<1	<0.1	<1	<1	3.90	0.140	<0.005	1.30	0.090	0.048	40	1.200	0.061
	6	760	2.4	<0.1	2.40	3.5	2,000	<1	<0.1	1.8	<1	3.10	0.130	0.007	1.00	0.080	0.034	37	0.920	0.068
8	7	590	1.2	<0.1	1.90	1.6	860	<1	<0.1	<1	<1	1.80	0.065	<0.005	0.62	<0.01	<0.005	30	0.620	0.019
	8	580	1.2	<0.1	1.90	1.5	940	<1	<0.1	<1	<1	2.60	0.077	<0.005	0.63	<0.01	<0.005	23	0.630	0.020
11	9	510	1.1	<0.1	<1	1.3	680	<1	<0.1	<1	<1	2.50	0.067	<0.005	0.57	<0.01	<0.005	25	0.570	0.017
	10	530	1.1	<0.1	1.20	<1	760	<1	<0.1	<1	<1	<1	0.070	<0.005	0.57	<0.01	<0.005	29	0.570	0.017
13	11	620	1.1	<0.1	1.10	<1	710	<1	nd	<1	<1	1.50	0.070	<0.005	0.58	<0.01	<0.005	34	0.580	0.013
	12	610	1.1	<0.1	2.10	<1	720	<1	nd	<1	<1	1.40	0.076	<0.005	0.54	<0.01	<0.005	29	0.540	0.015
Raff Ck	13	1100	<5	<1	22.00	<5	5,000	<1	<0.1	5.3	<5	11.00	0.071	0.069	0.93	nd	<0.005	24	0.920	0.004
	14	520	<5	<1	7.20	<5	1,300	<1	<0.1	<5	<5	<5	0.110	0.013	0.80	nd	<0.005	38	0.800	0.038
NEBP East	15	34	<5	<1	44.00	<5	2,100	<1	<0.1	<5	<5	<5	0.076	<0.005	0.95	nd	<0.005	7	0.950	0.002
NEBP West	16	93	<5	<1	<5	<5	580	<1	<0.1	<5	<5	7.50	0.350	<0.005	3.00	nd	0.006	28	3.000	0.170

Table 14. Results of ANOVAs examining variation in surface water chemistry over time (December 2005 - August 2006) in the Caboolture River. n = 2 replicates per site. DF = Degrees of Freedom, R = redundant term due to significant higher order interaction, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Times (Ti)	Site (Si)	Ti x Si	Residual
	DF:	1	5	5	12
Aluminium, µg/L (raw)	MS	3,825	106,883	80,966	646.880
	F -ratio	0.050	165.230	125.170	
	P	R	R	**<0.001**	
Copper, µg/L (raw)	MS	19.440	0.491	1.492	0.431
	F -ratio	13.030	1.140	3.460	
	P	R	R	**0.036**	
Iron, µg/L (raw)	MS	1,870,417	1,011,587	154,387	6308.330
	F -ratio	12.120	160.360	24.470	
	P	R	R	**<0.001**	
Zinc, µg/L (raw)*	MS	1,625	3,172	2,848	2968.590
	F -ratio	0.570	1.070	0.96	
	P	0.484	0.424	0.479	
Total Phosphorus, mg/L (raw)	MS	0.006	0.005	0.001	0.000
	F -ratio	11.470	135.300	15.770	
	P	R	R	**<0.001**	
Chlorophyll a, mg/L (Ln(x+1))	MS	8.542	1.903	1.001	0.042
	F -ratio	8.530	45.690	24.030	
	P	R	R	**<0.001**	
Total Nitrogen, mg/L (raw)*	MS	0.138	0.173	0.031	0.005
	F -ratio	4.470	37.070	6.620	
	P	R	R	**0.004**	
Ammonia, mg/L (raw)	MS	0.049	0.005	0.005	0.000
	F -ratio	9.300	108.970	110.860	
	P	R	R	**<0.001**	

Table 15. Water quality measured in surface waters of tidal creeks within the Project Site using a probe, March 2005 to July 2007. See Figure 4 for sampling locations. Stippled values are outside ANZECC (2000) Water Quality Guidelines. ND = no data due to faulty probe.

Location	Date-Sequential Station Number	Date	Time	Easting (WGS 84)	Northing (WGS 84)	Replicate	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
						ANZECC:			7.0-8.5		80-110		0.5-10
a. March 2005													
Adjacent to Marina basin	1	18/03/2005	1126	500838	7000645	1	24.34	35.08	ND	614	**70.7**	4.8	**0**
						2	24.42	35.10	ND	612	**69.1**	4.6	**0**
	2	18/03/2005	1140	500693	7000522	1	23.65	41.03	ND	614	**73.4**	4.9	**51.1**
						2	24.75	39.31	ND	611	**149.0**	10.1	**21.5**
Raff Creek	3	18/03/2005	1220	500184	7000926	1	24.20	36.59	ND	618	**40.5**	2.8	**0**
						2	24.48	33.90	ND	611	**111.0**	7.7	**66.3**
b. December 2005													
Raff Creek	1	14/12/2005	07:20	499409	7000723	1	28.18	5.98	**6.59**	89	**25.5**	1.9	ND
						2	28.15	6.21	**6.17**	98	**25.1**	1.9	ND
	2	14/12/2005	07:35	499409	7000723	1	28.30	6.00	**6.62**	113	**25.5**	1.9	ND
						2	27.71	5.66	**6.60**	126	**28.1**	2.1	**0.3**
	3	14/12/2005	07:50	499725	7000680	1	29.83	9.14	**6.77**	182	**33.0**	2.4	ND
						2	29.85	9.16	**6.82**	214	**32.8**	2.2	ND
Adjacent to Marina basin	4	14/12/2005	08:25	500846	7000682	1	29.72	20.07	7.21	160	**59.6**	4.1	ND
						2	29.73	20.06	7.27	143	**58.6**	4.0	**29.7**
	5	14/12/2005	08:40	500736	7000548	1	29.70	0.63	**6.27**	53	**18.5**	1.4	**23.9**
						2	29.70	0.75	**6.24**	104	**21.1**	1.6	**72.8**
	6	14/12/2005	08:50	500802	7000612	1	29.81	19.21	7.03	60	**57.0**	3.9	ND
						2	29.81	19.09	7.09	-13	**58.0**	3.9	**34.2**
Eastern sector	7	14/12/2005	09:10	501043	7000508	1	28.73	6.15	**6.42**	-231	**18.0**	1.0	**30.9**
						2	28.71	6.40	**6.44**	-118	**10.5**	0.8	**47.1**
	8	14/12/2005	09:15	501043	7000508	1	28.87	6.58	**6.43**	-129	**12.4**	1.0	**25.4**
						2	28.86	6.54	**6.42**	-131	**9.8**	0.7	**25.1**
Northern sector	9	14/12/2005	10:05	500484	7001789	1	31.13	7.09	**6.50**	86	96.0	6.9	**46.0**
						2	31.30	6.72	7.14	31	97.5	5.9	**61.7**

continued…

Table 15, continued

Location	Date-Sequential Station Number	Date	Time	Easting (WGS 84)	Northing (WGS 84)	Rep	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
						ANZECC:			**7.0-8.5**		**80-110**		**0.5-10**
c. January 2006													
Eatern sector	1	17/01/2006	11:10	501045	7000502	1	28.14	1.61	**6.50**	-5	**59.2**	3.1	**35.2**
						2	28.26	1.26	**6.22**	98	**60.6**	4.7	**21.7**
	2	17/01/2006	11:00	501064	7000537	1	27.65	6.10	**6.68**	120	**51.2**	3.9	**8.1**
						2	27.63	1.64	**6.51**	-68	**46.5**	3.6	**4.2**
	3	17/01/2006	10:50	500980	7000763	1	28.98	18.39	7.57	185	90.7	6.3	**14.8**
						2	28.85	18.43	7.59	176	91.1	6.3	**41.5**
Adjacent to Marina basin	4	17/01/2006	10:35	500848	7000679	1	29.49	1.52	**6.50**	136	**63.4**	4.8	**94.3**
						2	29.56	1.52	**6.43**	96	**59.4**	4.5	**106.2**
	5	17/01/2006	10:20	500865	7000694	1	29.30	18.18	7.61	83	92.0	6.4	**62.2**
						2	29.27	18.20	7.62	127	**89.3**	6.2	**52.0**
Raff Creek	6	17/01/2006	16:57	499411	7000725	1	28.75	1.57	**6.24**	31	**84.9**	6.5	**48.3**
						2	28.77	1.55	**6.21**	36	**84.1**	6.4	**36.1**
	7	17/01/2006	16:50	499454	7000727	1	28.97	1.72	**6.16**	41	92.9	7.1	**157.0**
						2	28.86	1.66	**6.17**	41	87.2	6.7	**65.0**
	8	17/01/2006	17:05	499704	7000709	1	29.03	10.60	**6.80**	5	**61.1**	4.5	**32.4**
						2	29.05	10.54	**6.86**	-23	**58.5**	4.2	**50.2**
Raff Creek	1	19/01/2006	10:00	501064	7000537	1	26.58	1.83	**6.56**	148	**48.2**	3.8	9.1
						2	26.56	1.84	**6.61**	105	**44.4**	3.5	8.8
	2	19/01/2006	11:20	499411	7000724	1	26.27	2.93	**6.54**	29	**73.4**	6.1	**26.2**
						2	26.53	3.83	**6.59**	18	**67.8**	5.3	**26.0**
	3	19/01/2006	11:45	499725	7000679	1	29.05	8.73	7.37	58	99.5	7.2	**30.6**
						2	29.26	9.01	7.38	62	99.8	7.2	**30.6**
Northern sector	4	19/01/2006	12:15	500487	7001783	1	27.17	6.62	7.61	86	**113**	9.2	**21.1**
						2	27.09	5.24	7.98	63	**164**	12.8	**24.7**
	5	19/01/2006	13:00	500335	7001502	1	27.14	8.46	7.63	65	**112**	8.5	**51.3**
						2	27.17	8.25	7.68	33	**110.3**	8.4	**42.4**
	6	19/01/2006	13:45	500329	7001267	1	28.79	14.28	7.46	82	**79.8**	5.7	**14.8**
						2	28.46	13.80	7.43	94	**79.2**	5.8	**17.9**

continued…

Table 15, continued

Location	Date-Sequential Station Number	Date	Time	Easting (WGS 84)	Northing (WGS 84)	Rep	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
						ANZECC:			**7.0-8.5**		**80-110**		**0.5-10**
d. April 2006													
Raff Creek	1	27/04/2006	12:35	499415	7000726	1	19.80	20.06	**6.99**	299	**62.5**	5.1	9.9
						2	19.81	20.05	**6.99**	301	**62.9**	5.1	9.2
	2	27/04/2006	12:28	499415	7000726	1	19.81	20.21	7.04	314	**62.1**	5.0	**13.0**
						2	19.81	20.15	7.01	391	**61.5**	5.0	**11.7**
	3	27/04/2006	12:47	498774	7000723	1	18.79	14.28	**6.81**	377	**17.4**	1.5	**49.6**
						2	18.85	14.49	**6.44**	381	**16.2**	1.4	**58.6**
	4	27/04/2006	12:55	498771	7000485	1	21.01	5.21	**6.56**	421	**18.6**	1.5	**93.3**
						2	19.81	5.41	**6.36**	449	**18.9**	1.6	**90.9**
	5	27/04/2006	13:15	498620	7000396	1	18.62	0.43	7.28	463	**42.4**	3.9	8.5
						2	20.18	0.44	7.10	458	**36.0**	3.2	9.8
	6	27/04/2006	13:26	498570	700092	1	26.02	0.11	7.43	466	**62.2**	5.0	**12.9**
						2	26.70	0.10	7.13	482	**69.2**	5.5	**10.3**
	7	27/04/2006	13:35	498568	7000099	1	17.96	0.00	7.67	693	**64.3**	6.6	**16.7**
						2	17.04	0.11	7.56	687	**27.8**	2.4	**17.5**
	8	27/04/2006	11:25	499720	70000681	1	22.23	21.21	7.56	432	**64.2**	4.9	**14.2**
						2	22.12	20.96	7.57	456	**65.3**	5.0	**10.4**
	9	27/04/2006	12:05	499091	7000697	1	18.49	19.86	**6.97**	286	**53.6**	4.4	**12.6**
						2	18.36	19.86	**6.84**	293	**55.1**	4.4	**12.0**
	10	27/04/2006	12:10	499234	7000687	1	19.03	19.97	7.02	278	**65.8**	5.4	8.0
						2	19.09	19.83	**6.96**	283	**64.6**	5.3	7.9
	11	27/04/2006	12:18	499318	7000673	1	19.50	19.69	**6.83**	273	**67.9**	5.5	9.5
						2	19.59	19.61	**6.81**	298	**68.6**	5.5	**22.1**
Adjacent to Marina basin	12	27/04/2006	09:35	500851	7000690	1	22.06	29.45	7.87	465	**70.4**	5.2	**12.5**
						2	20.07	29.46	7.88	465	**69.6**	5.1	**13.5**
	13	27/04/2006	10:11	500670	7000515	1	17.64	28.47	**6.83**	392	**52.3**	4.2	5.3
						2	16.94	28.47	**6.36**	406	**50.1**	4.0	4.0
	14	27/04/2006	10:28	500751	7000558	1	19.54	28.20	7.37	491	**68.2**	5.3	5.8
						2	19.79	28.08	7.39	47	**70.6**	5.4	9.6

continued…

Table 15, continued

Location	Date-Sequential Station Number	Date	Time	Easting (WGS 84)	Northing (WGS 84)	Rep	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
						ANZECC:			7.0-8.5		80-110		0.5-10
	15	27/04/2006	10:40	500796	7000595	1	20.00	28.14	7.46	453	**70**	5.4	5.1
						2	20.28	28.02	7.46	447	**70.8**	5.4	7.0
Eastern sector	16	27/04/2006	08:53	501042	7000507	1	18.06	22.97	**6.88**	553.0	**31.1**	2.4	3.0
						2	17.91	22.93	7.05	377	**34.6**	2.9	5.1
	17	27/04/2006	08:59	501042	7000507	1	17.90	22.94	7.06	387	**28.7**	2.4	4.4
						2	18.16	22.85	7.05	395	**25.6**	2.1	4.3
	18	27/04/2006	09:09	501058	7000520	1	18.26	22.59	7.32	444	**56.8**	4.7	**13.7**
						2	17.97	22.51	7.31	446	**59.6**	4.9	6.9
Northern sector	19	27/04/2006	14:05	500488	7001790	1	22.36	26.04	7.01	565	81.0	6.0	8.2
						2	22.73	26.06	**6.95**	517	**75.3**	5.6	9.2
	20	27/04/2006	14:15	500339	7001519	1	23.60	25.37	7.19	467	94.4	6.9	**11.3**
						2	23.56	25.39	7.05	453	85.9	6.3	**10.6**
e. August 2006													
Northern Sector	1	20/08/2006	11:00	500356	7002014	1	16.13	36.03	**5.44**	375	92.6	7.3	5.4
						2	16.28	35.73	**5.44**	372	97.3	7.7	6.9
	2	20/08/2006	11:10	500482	7001788	1	15.51	34.11	**6.35**	370	109.4	8.7	3.8
						2	15.55	33.98	**6.51**	370	95.5	7.8	ND
	3	20/08/2006	11:20	500343	7001524	1	15.83	35.60	**6.97**	383	92.3	7.4	2.9
						2	15.11	35.17	7.00	379	84.5	6.9	2.2
	4	20/08/2006	11:27	500350	7001444	1	17.63	37.89	7.49	389	147.8	11.1	5.8
						2	17.56	37.88	7.37	401	141.8	10.7	6.6

continued…

Table 15, continued

Location	Date-Sequential Station Number	Date	Time	Easting (WGS 84)	Northing (WGS 84)	Rep	Temp C	Salinity ppt	pH	ORP mv	DO%	DO mg/L	Turbidity ntu
						ANZECC:			**7.0-8.5**		**80-110**		**0.5-10**
f. July 2007	1	16/07/07	0950	500800	7000617	1	9.20	29.86	**5.80**	451.00	85.70	8.20	5.10
						2	9.80	29.91	**6.36**	430.00	87.00	8.40	2.83
	2	16/07/07	1035	500655	7000501	1	11.50	24.52	**4.53**	481.00	**137.00**	12.70	5.97
						2	12.98	29.82	**5.30**	466.00	80.30	7.10	6.43
	3	16/07/07	1057	500615	7000292	1	17.50	26.60	**3.90**	511.00	**147.00**	12.10	9.73
						2	15.70	26.70	**3.93**	515.00	**146.00**	12.20	**10.80**
	4	16/07/07	1305	501045	7000505	1	13.16	25.20	**5.91**	512.00	88.00	7.90	1.50
						2	15.60	24.60	**6.19**	504.00	94.00	8.30	1.37
	5	16/07/07	1308	501087	7000456	1	17.73	26.00	**6.28**	496.00	82.00	6.70	7.30
						2	18.10	25.20	**6.47**	486.00	94.00	7.50	4.47
	6	16/07/07	1300	500993	7000747	1	18.60	25.30	**6.10**	501.00	89.00	7.80	4.87
						2	18.40	27.40	**6.30**	506.00	90.00	7.90	4.40
	7	17/07/07	1100	499688	7000725	1	11.29	20.35	**5.65**	370.00	**74.70**	7.30	7.73
						2	11.20	20.30	**5.67**	370.00	**75.00**	7.20	8.47
	8	17/07/07	1136	499654	7000949	1	14.27	20.93	**6.37**	428.00	90.60	0.20	**10.27**
						2	14.33	21.14	**6.74**	428.00	89.40	0.20	**10.67**
	9	17/07/07	1150	499413	7000741	1	12.69	25.03	**6.46**	430.00	**38.60**	3.60	1.87
						2	13.30	21.30	**6.50**	426.00	84.00	7.70	6.53
	10	30/07/07	1004	500456	7001900	ND							
	11	30/07/07	0934	500267	7001363	ND							
	12	30/07/07	0911	500162	7001213	ND							

Table 16. Sediment chemistry, samples collected by The Ecology Lab in April 2006 (mg/kg dry weight). See Figures 3 & 4 for sampling sites.

Location	Description	SITE (S) &/or REPLICATE (R) No.	Al	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Se	Zn	TP	TN	NOx	TKN	TOC	Total Solids
		ANZECC ISQG-low:	**-**	**20**	**1.5**	**80**	**65**	**-**	**50**	**0.15**	**21**	**-**	**200**	**-**	**-**	**-**	**-**	**-**	**-**
		ANZECC ISQG-high:	**-**	**70**	**10**	**370**	**270**	**-**	**220**	**1**	**52**	**-**	**410**	**-**	**-**	**-**	**-**	**-**	**-**
River Channel	D/s of Bruce Hwy Bridge	S4R1	7,360	4	<0.5	24	10	13,900	5.0	<0.2	8.7	<0.5	28	230	480	<1	480	7,700	64.4
		S4R2	23,900	12	<0.5	69	31	48,100	15.0	<0.2	24	0.60	88	840	1,500	<1	1,500	23,000	38.2
	u/s Goong Creek	S6R1	2,310	2.9	<0.5	9.3	3.2	6,160	1.5	<0.2	4	<0.5	9.2	110	55	<1	55	2,200	79.9
		S6R2	4,920	3	<0.5	16	6	9,590	3.2	<0.2	5.8	<0.5	17	180	110	<1	110	2,800	74.4
	Opposite Raff Creek	S8R1	21,400	9.8	<0.5	59	25	40,300	13.0	<0.2	21	<0.5	63	580	1,500	<1	1,500	20,000	44.9
		S8R2	21,400	9.8	<0.5	57	24	40,900	12.0	<0.2	20	<0.5	63	590	1,400	<1	1,400	19,000	43.8
	Opposite prop marina entrance	S9R1	13,300	11	<0.5	33	14	27,300	7.7	<0.2	12	<0.5	41	470	1,200	<1	1,200	11,000	54.9
		S9R2	14,800	8.1	<0.5	43	17	28,700	8.7	<0.2	16	<0.5	47	430	1,000	<1	1,000	13,000	55.0
	Opposite Monti's Marina	S11R1	18,900	19	<0.5	66	100	45,800	17.0	<0.2	26	<0.5	100	680	1,100	<1	1,100	11,000	49.1
		S11R2	23,000	15	<0.5	63	160	43,400	17.0	<0.2	24	<0.5	110	600	1,500	<1	1,500	19,000	42.0
	Opposite King John Ck	S12R1	8,640	9.5	<0.5	24	8.6	18,100	5.3	<0.2	8.8	<0.5	27	280	590	<1	590	8,200	60.1
		S12R2	13,000	5.3	<0.5	31	12	22,700	7.4	<0.2	11	<0.5	35	270	710	<1	710	7,200	63.8
	Shallow, broad navigation channel	S13R1	910	3.9	<0.5	4.8	0.76	4,680	1.2	<0.2	1.8	<0.5	6.2	110	<30	<1	<30	560	78.3
		S13R2	950	4	<0.5	5.7	0.76	4,600	1.0	<0.2	1.7	<0.5	6.2	110	46	<1	46	660	77.3
Project site	East sector	NEBP1	22,200	13	<0.5	50	39	65,100	14.0	<0.2	69	0.91	240	1,210	7,500	<1	7,500	120,000	13.6
	Adj. to marina basin	NEBP2	29,900	24	<0.5	56	27	76,000	15.0	<0.2	55	0.82	300	1,630	13,000	<1	13,000	67,000	25.1
	Raff Creek	NEBP3	18,600	24	<0.5	54	16	34,800	11.0	<0.2	16	<0.5	34	460	2,300	<1	2,300	31,000	48.6
	Raff Creek	NEBP4	50,000	15	<0.5	64	57	20,500	29.0	<0.2	22	1.30	31	700	2,300	<1	2,300	37,000	43.2
	Raff Creek	NEBP5	27,500	9.2	<0.5	68	52	21,900	24.0	<0.2	9.6	0.53	26	160	600	<1	600	17,000	47.5
	North sector	NEBP6	14,900	4.3	<0.5	64	31	14,800	9.5	<0.2	18	<0.5	38	400	2,500	1	2,500	32,000	55.7
	North sector	NEBP7	20,000	9.7	<0.5	71	30	26,800	10.0	<0.2	21	<0.5	46	790	3,000	<1	3,000	37,000	44.7

Table 17. Results of ANOVAs examining variation in sediment quality across sites (April 2006) in the Caboolture River. *n* = 2 replicates per site. DF = Degrees of Freedom, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Site (Si)	Residual
	DF:	5	12
Aluminium, µg/L (Ln(x))	MS	2.630	0.160
	F -ratio	16.940	
	P	**0.001**	
Copper, µg/L (Sqrt x)	MS	21.224	0.943
	F -ratio	22.510	
	P	**<0.001**	
Iron, µg/L (raw)*	MS	466945.398	86475.093
	F -ratio	5.400	
	P	**0.022**	
Zinc, µg/L (Ln(x+1))*	MS	1.730	0.119
	F -ratio	14.500	
	P	**0.001**	
Total Phosphorus, mg/L (raw)*	MS	92261.900	27541.290
	F -ratio	3.350	
	P	0.069	
Total Nitrogen mg/L (Ln(x))	MS	4.970	0.229
	F -ratio	21.730	
	P	**<0.001**	
Organic Carbon, mg/L (raw)*	MS	98857.933	21747.143
	F -ratio	4.550	
	P	**0.034**	

Table 18. Summary of data collected on benthic invertebrates living in channel sediments (subtidal) of the Caboolture River.

Phylum or Order	Family	Occurrence (Cores)	Total	% Contribution
POLYCHAETES Class Polychaeta	Capitellidae	28	140	19.00
	Eunicidae	1	1	0.14
	Glyceridae	5	11	1.49
	Magelonidae	4	5	0.68
	Nereididae	5	8	1.09
	Oweniidae	4	26	3.53
	Sabellidae	17	136	18.45
	Spionidae	17	41	5.56
CRUSTACEANS Order: Mysidacea	Mysidae	4	8	1.09
Order: Amphipoda	Melitidae	3	17	2.31
	Oedicerotidae	3	4	0.54
Order: Isopoda	Sphaeromatidae	1	1	0.14
Order: Tanaidacea	Apseudidae	12	59	8.01
Order: Cumacea	Bodotriidae	1	1	0.14
IOrder Anomura	Diogenidae	1	1	0.14
MOLLUSCS Class Gastropoda	Nassariidae	6	6	0.81
SubClass Opisthobranchia	Acteonidae	1	1	0.14
Class Bivalva	Cardiidae	1	1	0.14
	Galeommatidae	8	23	3.12
	Mactridae	11	32	4.34
	Mytilidae	1	1	0.14
	Psammobiidae/Tellinidae	8	13	1.76
Nematoda	-	2	4	0.54
Nemertea	-	3	10	1.36
Oligochaeta	-	19	171	23.20
Anthozoa: Actinaria	-	3	4	0.54
Bryozoa	-	1	1	0.14
Hydrozoa	-	11	11	1.49
Summary statistics based on taxa:				
		Total number of taxa	28	100.0
		Number of Polychaete taxa	8	28.6
		Number of Crustacean taxa	7	25.0
		Number of Mollusc taxa	7	25.0
		Number of other worm phyla taxa	3	10.7
		Number of other phlya taxa	3	10.7
Summary Statistics based on abundance:				
		Total number of individuals	737	100.0
		Number of Polychaetes	368	49.9
		Number of Crustaceans	91	12.3
		Number of Molluscs	77	10.4
		Number of of other worm phyla	185	25.1
		Number of other phlya	16	2.2

Table 19. Mean and standard error (SE; n = 4) of samples collected in the main river channel of the Caboolture River, April 2006. See Figure 3 for site positions.

Taxon	Site 4		Site 5		Site 6		Site 8		Site 9	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Capitellidae	9.75	5.07	10.5	4.41	6.5	2.02	2.5	0.87	0.5	0.29
Eunicidae	0	0.00	0	0.00	0	0.00	0.25	0.25	0	0.00
Glyceridae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Magelonidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Nereididae	0	0.00	0	0.00	0.75	0.75	0.75	0.48	0	0.00
Oweniidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sabellidae	0	0.00	0	0.00	8.5	3.20	0.25	0.25	6.25	1.70
Spionidae	0	0.00	0.25	0.25	0.5	0.29	2	1.35	1.75	0.63
Mysidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Melitidae	0	0.00	0	0.00	0	0.00	4.25	2.17	0	0.00
Oedicerotidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sphaeromatidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Apseudidae	0	0.00	0.5	0.50	5	2.04	7	3.14	0.5	0.50
Bodotriidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Diogenidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Nassariidae	0	0.00	0	0.00	0	0.00	0	0.00	0.25	0.25
Acteonidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Cardiidae	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Galeommatidae	0	0.00	0	0.00	0	0.00	0	0.00	0.5	0.50
Mactridae	0	0.00	0	0.00	0	0.00	0	0.00	0.25	0.25
Mytilidae	0	0.00	0	0.00	0	0.00	0.25	0.25	0	0.00
Psammobiidae (Tellinidae)	0	0.00	0	0.00	0	0.00	0.25	0.25	0	0.00
Nematoda	0	0.00	0.25	0.25	0.75	0.75	0	0.00	0	0.00
Nemertea	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Oligochaeta	8.75	6.50	18.25	4.92	11.25	2.95	1.5	0.50	2.5	1.19
Anthozoa: Actinaria	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Bryozoa	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Hydrozoa	0.25	0.25	0	0.00	1	0.00	0.75	0.25	0.25	0.25
Total number of taxa	1.75	0.63	2.75	0.48	6	0.41	6.25	0.63	4.25	1.11
Number of Polychaete taxa	0.75	0.25	1.25	0.25	2.75	0.25	2.75	0.25	2.25	0.48
Number of Crustacean taxa	0	0.00	0.25	0.25	1	0.00	1.5	0.50	0.25	0.25
Number of Mollusc taxa	0	0.00	0	0.00	0	0.00	0.5	0.29	0.75	0.25
Number of other worm phyl	0.75	0.25	1.25	0.25	1.25	0.25	0.75	0.25	0.75	0.25
Number of other phlya taxa	0.25	0.25	0	0.00	1	0.00	0.75	0.25	0.25	0.25
Total number of individuals	18.75	10.96	29.75	4.27	34.25	8.61	19.75	6.02	12.75	2.06
Number of Polychaetes	9.75	5.07	10.75	4.31	16.25	5.33	5.75	1.55	8.5	1.85
Number of Crustaceans	0	0.00	0.5	0.50	5	2.04	11.25	4.77	0.5	0.50
Number of Molluscs	0	0.00	0	0.00	0	0.00	0.5	0.29	1	0.41
Number of of other worm pl	8.75	6.50	18.5	5.14	12	3.34	1.5	0.50	2.5	1.19
Number of other phlya	0.25	0.25	0	0.00	1	0.00	0.75	0.25	0.25	0.25

continued…

Table 19, continued

Taxon	Site 11		Site 12		Site 13		Site 14	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Capitellidae	1.5	0.50	1.5	0.65	0.25	0.25	2	0.00
Eunicidae	0	0.00	0	0.00	0	0.00	0	0.00
Glyceridae	0.25	0.25	2	1.22	0.25	0.25	0.25	0.25
Magelonidae	0.25	0.25	1	0.41	0	0.00	0	0.00
Nereididae	0.25	0.25	0	0.00	0.25	0.25	0	0.00
Oweniidae	0	0.00	6.5	0.96	0	0.00	0	0.00
Sabellidae	15.25	4.59	3.75	1.18	0	0.00	0	0.00
Spionidae	3.25	1.11	0	0.00	2.25	1.03	0.25	0.25
Mysidae	0	0.00	0	0.00	1.25	0.95	0.75	0.48
Melitidae	0	0.00	0	0.00	0	0.00	0	0.00
Oedicerotidae	0	0.00	0	0.00	0.75	0.48	0.25	0.25
Sphaeromatidae	0.25	0.25	0	0.00	0	0.00	0	0.00
Apseudidae	1.75	0.85	0	0.00	0	0.00	0	0.00
Bodotriidae	0.25	0.25	0	0.00	0	0.00	0	0.00
Diogenidae	0	0.00	0	0.00	0	0.00	0.25	0.25
Nassariidae	0.25	0.25	0.5	0.29	0.25	0.25	0.25	0.25
Acteonidae	0	0.00	0	0.00	0	0.00	0.25	0.25
Cardiidae	0	0.00	0	0.00	0	0.00	0.25	0.25
Galeommatidae	0	0.00	0.5	0.50	2.5	1.32	2.25	1.03
Mactridae	2.25	1.60	4.25	0.25	1.25	0.48	0	0.00
Mytilidae	0	0.00	0	0.00	0	0.00	0	0.00
Psammobiidae (Tellinidae)	0	0.00	1.75	0.25	1	0.58	0.25	0.25
Nematoda	0	0.00	0	0.00	0	0.00	0	0.00
Nemertea	0	0.00	0	0.00	2.5	1.04	0	0.00
Oligochaeta	0.5	0.29	0	0.00	0	0.00	0	0.00
Anthozoa: Actinaria	0	0.00	0	0.00	0.25	0.25	0.75	0.48
Bryozoa	0	0.00	0.25	0.25	0	0.00	0	0.00
Hydrozoa	0.5	0.29	0	0.00	0	0.00	0	0.00
Total number of taxa	6.75	1.44	7	0.71	5.75	0.63	4.75	0.75
Number of Polychaete taxa	3.5	0.50	4	0.58	1.5	0.50	1.5	0.29
Number of Crustacean taxa	1.25	0.63	0	0.00	1	0.41	1	0.00
Number of Mollusc taxa	1	0.41	2.75	0.25	2.25	0.48	1.75	0.48
Number of other worm phyl	0.5	0.29	0	0.00	0.75	0.25	0	0.00
Number of other phlya taxa	0.5	0.29	0.25	0.25	0.25	0.25	0.5	0.29
Total number of individuals	26.5	5.95	22	1.08	12.75	3.07	7.75	1.55
Number of Polychaetes	20.75	4.85	14.75	1.25	3	1.22	2.5	0.29
Number of Crustaceans	2.25	0.85	0	0.00	2	1.08	1.25	0.25
Number of Molluscs	2.5	1.55	7	0.41	5	0.91	3.25	1.11
Number of of other worm pl	0.5	0.29	0	0.00	2.5	1.04	0	0.00
Number of other phlya	0.5	0.29	0.25	0.25	0.25	0.25	0.75	0.48

Table 20. Results of ANOSIM analyses of benthic invertebrate assemblages in Caboolture River channel in April 2006.

Channel (sub-tidal)		R-value	Probability
Global R		0.574	$p < 0.001$
Pairwise contrasts:			
	upper vs middle	0.485	$p < 0.001$
	upper vs lower	0.764	$p < 0.001$
	middle vs lower	0.497	$p < 0.001$

Table 21. Results of SIMPER analyses of macro-invertebrate assemblages in channel locations at Caboolture in April 2006. Taxa listed account for > 90% of dissimilarities.

Upper Reaches vs Middle Reaches

Dissimilarity 77.74%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oligochaeta	13.91	1.50	23.98	1.45	30.85	30.85
Capitellidae	9.73	1.50	17.25	1.16	22.19	53.04
Sabellidae	3.09	7.25	15.33	1.07	19.72	72.76
Apseudidae	2.00	3.08	7.41	0.91	9.53	82.28
Spionidae	0.27	2.33	4.52	1.07	5.82	88.10
Melitidae	0.00	1.42	2.85	0.44	3.67	91.76

Upper Reaches vs Lower Reaches

Dissimilarity 91.84%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oligochaeta	13.91	0.00	30.15	1.72	32.83	32.83
Capitellidae	9.73	1.25	19.09	1.18	20.78	53.61
Sabellidae	3.09	1.25	7.36	0.81	8.02	61.63
Galeommatidae	0.00	1.75	4.86	0.77	5.29	66.92
Oweniidae	0.00	2.17	4.63	0.61	5.04	71.96
Mactridae	0.00	1.83	4.19	0.92	4.56	76.52
Apseudidae	2.00	0.00	4.17	0.66	4.54	81.07
Spionidae	0.27	0.83	2.37	0.64	2.58	83.65
Psammobiidae/Tellinidae	0.00	1.00	2.30	0.95	2.51	86.16
Nemertea	0.00	0.83	2.05	0.49	2.23	88.39
Mysidae	0.00	0.67	1.96	0.52	2.13	90.52

Middle Reaches vs Lower Reaches

Dissimilarity 85.93%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sabellidae	7.25	1.25	20.45	1.08	23.80	23.80
Apseudidae	3.08	0.00	8.33	0.78	9.70	33.50
Spionidae	2.33	0.83	6.56	1.22	7.63	41.13
Galeommatidae	0.17	1.75	6.03	0.90	7.01	48.14
Mactridae	0.83	1.83	5.68	1.10	6.61	54.75
Oweniidae	0.00	2.17	5.59	0.63	6.50	61.25
Oligochaeta	1.50	0.00	5.30	0.85	6.17	67.42
Capitellidae	1.50	1.25	4.31	1.16	5.01	72.43
Melitidae	1.42	0.00	3.87	0.45	4.51	76.94
Psammobiidae/Tellinidae	0.08	1.00	2.80	1.05	3.26	80.21
Nemertea	0.00	0.83	2.51	0.51	2.92	83.13
Mysidae	0.00	0.67	2.44	0.58	2.84	85.98
Glyceridae	0.08	0.83	2.26	0.59	2.63	88.60
Hydrozoa	0.50	0.00	1.59	0.80	1.85	90.46

Table 22. a) Results of ANOVAs examining variation in abundances of macroinvertebrate taxa contributing 5% or more to dissimilarities between channel locations (April 2006) in the Caboolture River. *n* = 2 replicates per site. DF = Degrees of Freedom, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test). b) Comparison of means using SNK tests. Magnitude of means increases from left to right.

a. ANOVA results

Indicator	**Factor:**	Locations (Lo)	Sites (Lo)	Residual
	DF:	2	6	27
Capitellidae (Sqrt x)*	MS	7.830	0.350	0.750
	F -ratio	22.210	0.470	
	P	**0.002**		
Sabellidae (Ln(x+1))	MS	3.870	5.070	0.160
	F -ratio	0.760	31.820	
	P	0.507	**<0.001**	
Spionidae (raw)	MS	13.861	2.972	2.102
	F -ratio	6.590	1.410	
	P	**0.001**	0.246	
Apseudidae (Ln(x+1))*	MS	2.728	1.617	0.349
	F -ratio	1.690	4.640	
	P	0.262	**0.002**	
Oweniidae (raw)*	MS	18.778	18.778	0.405
	F -ratio	1.000	46.090	
	P	0.422		
Galeommatidae (Ln(x+1))	MS	2.026	0.263	0.214
	F -ratio	7.710	1.230	
	P	**0.022**	0.324	
Mactridae (Ln(x+1))	MS	1.894	1.198	0.129
	F -ratio	1.580	9.310	
	P	0.281	**<0.001**	
Oligochaeta (raw)*	MS	582.750	33.670	34.190
	F -ratio	17.310	0.980	
	P	**0.003**	0.455	

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Table 22 continued

b. Outcome of SNK Tests

Indicator	Test	SNK Outcome
Capitellidae	Location	3 = 2 < 1
Sabellidae	Location	3 = 1 = 2
Spionidae	Location	3 = 1 = 2
Apseudidae	Location	1 = 3 = 2
Oweniidae	Location	3 = 1 = 2
Galeommatidae	Location	1 = 2 < 3
Mactridae	Location	1 = 2 = 3
Oligochaeta	Location	3 = 2 < 1

Table 23. Results of SNK analyses based on ANOVAs comparing benthic invertebrates in channel locations and sites.

Taxon	Comparison of locations		
	upper vs middle	upper vs lower	middle vs lower
Capitellidae	$p < 0.01$	$p < 0.01$	ns
Sabellidae	ns	ns	ns
Spionidae	ns	$p < 0.01$	$p < 0.05$
Apseudidae	ns	ns	ns
Oweniidae	ns	ns	ns
Galeommatidae	$p < 0.05$	$p < 0.05$	ns
Mactridae	ns	ns	ns
Oligochaeta	$p < 0.01$	$p < 0.01$	ns

Table 24. Summary of data collected on benthic invertebrates living in bank sediments (intertidal) of the Caboolture River.

Phylum or Order	Family	Occurrence (Cores)	Total	% Contribution
POLYCHAETES Class Polychaeta	Capitellidae	19	50	12.02
	Eunicidae	4	4	0.96
	Lumbrineridae	5	7	1.68
	Magelonidae	1	2	0.48
	Nereididae	11	19	4.57
	Opheliidae	8	27	6.49
	Sabellidae	12	88	21.15
	Spionidae	3	10	2.40
CUSTACEANS Order: Amphipoda	Aoridae/Isaeida	12	50	12.02
	Melitidae	9	25	6.01
Order: Tanaidacea	Apseudidae	9	74	17.79
IOrder Brachyura	Ocypodidae	7	8	1.92
	Portunidae	1	2	0.48
SubClass Copepoda	Copepoda	1	2	0.48
MOLLUSCS Class Bivalva	Galeommatidae	3	11	2.64
	Mactridae	3	14	3.37
	Tellinidae	4	6	1.44
OTHER WORM PHYLA	Oligochaeta	8	16	3.85
OTHER PHYLA	Bryozoa	1	1	0.24
Summary statistics based on taxa				
Total number of taxa			19	100
Number of Polychaete taxa			8	42.11
Number of Crustacean taxa			6	31.58
Number of Mollusc taxa			3	15.79
Number of other worm phyla taxa			1	5.26
Number of other phlya taxa			1	5.26
Summary Statistics based on abundance				
Total number of individuals			416	100
Number of Polychaetes			207	49.76
Number of Crustaceans			161	38.70
Number of Molluscs			31	7.45
Number of of other worm phyla			16	3.85
Number of other phlya			1	0.24

Table 25. Mean and standard error (SE; n = 4) for samples of benthic invertebrates collected in the intertidal zone of bank locations along the Caboolture River, April 2006. See Figure 5 for site positions.

Taxon	Upstream of Marina entrance				Adjacent to Marina entrance				Downstream of Marine entrance			
	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Capitellidae	2.00	0.41	0.25	0.25	0.75	0.25	4.50	2.06	4.00	0.82	1.00	0.41
Eunicidae	0.25	0.25	0.50	0.29	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Lumbrineridae	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	1.00	0.41	0.25	0.25
Magelonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00
Nereididae	1.50	0.50	1.00	0.71	0.00	0.00	1.00	0.71	1.25	0.48	0.00	0.00
Opheliidae	0.00	0.00	4.25	1.31	0.50	0.50	0.25	0.25	1.75	1.18	0.00	0.00
Sabellidae	0.00	0.00	0.50	0.50	16.25	4.59	1.00	0.71	4.00	0.41	0.25	0.25
Spionidae	0.00	0.00	1.75	1.75	0.00	0.00	0.00	0.00	0.75	0.48	0.00	0.00
Aoridae/Isaeidae/Photidae/Unciolidae	0.75	0.25	7.25	4.39	1.50	0.87	2.50	1.66	0.50	0.29	0.00	0.00
Melitidae	3.75	1.11	0.25	0.25	0.00	0.00	0.00	0.00	2.25	0.48	0.00	0.00
Apseudidae	1.50	1.19	14.75	2.50	0.25	0.25	0.00	0.00	2.00	1.68	0.00	0.00
Ocypodidae	0.25	0.25	0.75	0.48	0.00	0.00	0.25	0.25	0.25	0.25	0.50	0.29
Portunidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00
Copepoda	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Galeommatidae	1.50	1.50	1.25	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mactridae	3.00	1.78	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tellinidae	0.00	0.00	1.25	0.48	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Oligochaeta	1.25	0.25	0.00	0.00	2.25	1.65	0.50	0.29	0.00	0.00	0.00	0.00
Bryozoa	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Summary statistics based on taxa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total number of taxa	6.50	0.65	6.75	0.48	3.75	0.75	3.75	0.75	7.75	0.85	1.75	0.75
Number of Polychaete taxa	2.25	0.25	2.75	0.48	2.00	0.41	2.50	0.65	5.00	0.71	1.25	0.48
Number of Crustacean taxa	2.50	0.29	2.50	0.29	1.00	0.41	0.75	0.48	2.50	0.29	0.50	0.29
Number of Mollusc taxa	0.75	0.25	1.50	0.29	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Number of other worm phyla taxa	1.00	0.00	0.00	0.00	0.50	0.29	0.50	0.29	0.00	0.00	0.00	0.00
Number of other phlya taxa	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Summary Statistics based on abundance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total number of individuals	15.75	3.54	34.25	5.09	22.25	4.61	10.50	4.50	19.25	2.75	2.00	0.91
Number of Polychaetes	3.75	1.11	8.25	2.36	17.50	3.97	7.25	3.22	13.50	2.02	1.50	0.65
Number of Crustaceans	6.25	2.17	23.00	3.19	2.25	0.85	2.75	1.70	5.50	1.71	0.50	0.29
Number of Molluscs	4.50	1.55	3.00	1.08	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00
Number of of other worm phyla	1.25	0.25	0.00	0.00	2.25	1.65	0.50	0.29	0.00	0.00	0.00	0.00
Number of other phlya	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Results of ANOSIM analyses of assemblages of benthic invertebrate in bank locations at Caboolture in August 2006.

Bank (Littoral)	R-value	Probability
Global R	0.295	p < 0.002
Pairwise contrasts:		
upstream vs marina entrance	0.438	p < 0.001
upstream vs downstream	0.348	p < 0.004
marina entrance vs downstream	0.103	ns

Table 27. Results of SIMPER analyses of assemblages of benthic macroinvertebrates in bank locations at Caboolture in August 2006. Taxa listed account for > 90% of dissimilarities.

Upstream vs Marina

Dissimilarity 85.54%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sabellidae	0.25	8.63	18.68	0.93	21.84	21.84
Apseudidae	8.13	0.13	18.35	1.05	21.45	43.29
Aoridae/Isaeidae/Photidae/Unciolidae	4.00	2.00	9.27	1.00	10.84	54.13
Melitidae	2.00	0.00	6.27	0.89	7.32	61.45
Capitellidae	1.13	2.63	6.26	0.84	7.32	68.77
Mactridae	1.75	0.00	5.27	0.57	6.16	74.93
Opheliidae	2.13	0.38	4.36	0.97	5.10	80.03
Oligochaeta	0.63	1.38	3.70	0.80	4.32	84.35
Galeommatidae	1.38	0.00	3.60	0.57	4.21	88.56
Nereididae	1.25	0.50	3.51	1.11	4.10	92.66

Upstream vs Downstream

Dissimilarity 80.29%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Apseudidae	8.13	1.14	20.30	1.08	25.29	25.29
Aoridae/Isaeidae/Photidae/Unciolidae	4.00	0.29	8.05	0.75	10.03	35.32
Melitidae	2.00	1.29	6.99	0.95	8.71	44.02
Sabellidae	0.25	2.43	6.34	1.10	7.90	51.92
Mactridae	1.75	0.00	6.08	0.56	7.57	59.49
Capitellidae	1.13	2.86	5.47	1.34	6.81	66.30
Opheliidae	2.13	1.00	5.36	1.02	6.67	72.98
Nereididae	1.25	0.71	4.11	1.07	5.12	78.09
Galeommatidae	1.38	0.00	4.04	0.57	5.04	83.13
Oligochaeta	0.63	0.00	3.19	0.57	3.97	87.10
Spionidae	0.88	0.43	2.26	0.58	2.81	89.91
Lumbrineridae	0.00	0.71	2.12	0.88	2.64	92.55

Marina vs Downstream

Dissimilarity 74.76%

Taxon	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Sabellidae	8.63	2.43	25.96	1.07	34.73	34.73
Capitellidae	2.63	2.86	10.44	0.95	13.97	48.70
Aoridae/Isaeidae/Photidae/Unciolidae	2.00	0.29	8.72	0.79	11.67	60.37
Nereididae	0.50	0.71	4.30	0.67	5.75	66.12
Oligochaeta	1.38	0.00	4.09	0.73	5.47	71.58
Melitidae	0.00	1.29	3.88	0.95	5.19	76.78
Opheliidae	0.38	1.00	3.72	0.72	4.97	81.75
Apseudidae	0.13	1.14	3.61	0.54	4.82	86.57
Lumbrineridae	0.25	0.71	3.16	0.89	4.23	90.80

Table 28. Results of ANOVAs examining variation in abundances of benthic invertebrate taxa contributing 5% or more to dissimilarities between bank locations (August 2006) in the Caboolture River. n = 2 replicates per site. DF = Degrees of Freedom, significant factors highlighted in bold, for each indicator data format used for analyses shown in brackets, those formats with an astersk had heterogeneous variances (Cochran's C test).

Indicator	**Factor:**	Locations (Lo)	Sites (Lo)	Residual
	DF:	2	3	18
Capitellidae (Ln(x+1))*	MS	0.490	1.700	0.230
	F -ratio	0.290	7.230	
	P	0.769	**0.002**	
Nereididae (raw)	MS	1.290	1.880	0.990
	F -ratio	0.690	1.900	
	P	0.567	0.166	
Opheliidae (raw)	MS	6.500	14.130	2.290
	F -ratio	0.460	6.160	
	P	0.669	**0.005**	
Sabellidae (Ln(x+1))	MS	4.290	4.527	0.240
	F -ratio	0.950	18.870	
	P	0.480	**<0.001**	
Aordidae (Ln(x+1))	MS	1.661	0.894	0.594
	F -ratio	1.860	1.510	
	P	0.299	0.247	
Melitidae (Ln(x+1))*	MS	1.396	1.962	0.090
	F -ratio	0.710	21.770	
	P	0.559	**<0.001**	
Apseudidae (Sqrt x)	MS	6.365	4.266	0.277
	F -ratio	1.490	15.380	
	P	0.355	**<0.001**	
Galeommatidae (Ln(x+1))*	MS	0.752	0.005	0.255
	F -ratio	141.880	0.020	
	P	**0.001**	0.996	
Mactridae (Ln(x+1))*	MS	1.029	0.320	0.261
	F -ratio	3.210	1.230	
	P	0.180	0.328	

Table 29. Results of SNK analyses based on ANOVAs comparing benthic invertebrates sampled at bank locations and sites within locations.

Taxon	Comparison of locations		
	upstream vs marina	upstream vs downstream	marina vs downstream
Capitellidae	ns	ns	ns
Nereididae	ns	ns	ns
Opheliidae	ns	ns	ns
Sabellidae	ns	ns	ns
Apseudidae	ns	ns	ns
Aoridae	ns	ns	ns
Galeommatidae	$p < 0.01$	$p < 0.01$	ns
Mactridae	ns	ns	ns
Meltidae	ns	ns	ns

Table 30. Fish and crustaceans collected by bait trapping (*n* = 96 samples from 16 sites) within tidal channels adjoining the Caboolture River, January 2006 and July 2007. Includes sites within NEBP project site and control sites outside NEBP. See Figure 6 for trapping positions.

a. January 2006

Family	Scientific name	Common Name	Occurrence	Total	Mean	SE
Fish:						
Poecilidae	*Gambusia holbrooki*	Mosquito Fish	34	1979	20.61	5.99
	Xiphophorus maculatus	Platyfish	2	2	0.02	0.01
Pseudomugilidae	*Pseudomugil signifer*	Common Blue-eye	21	510	5.31	1.79
Ambassidae	*Ambassis marianus*	Ramsay's Glassfish	18	136	1.42	0.63
Sparidae	*Acanthopagrus australis*	Yellowfin Bream	2	2	0.02	0.01
Mugilidae	*Mugil georgii*	Fantail Mullet	2	2	0.02	0.01
Gobiidae	*Mugilogobius paludis*	Mangrove Goby	24	78	0.81	0.21
	Pseudogobius olorum	Blue-spot Goby	8	14	0.15	0.06
Tetraodontidae	*Torquigoner pleurosticta*	Banded Toadfish	14	30	0.31	0.13
	Tetractenos hamiltoni	Common Toad	5	8	0.08	0.05
Totals:			**10**	**2761**		
Invertebrates:						
Dytiscidae		Diving Beetle	2	4	0.04	0.03
Portunidae	*Scylla serrata*	Mud Crab	1	1	0.01	0.01
Caridae	*Macrobrachium* sp.	Carid shrimp	28	127	1.32	0.30
	Palaemonetes sp.	Estuarine Shrimp	4	13	0.14	0.08
Penaeidae	*Penaeus* sp.	Prawn	19	43	0.45	0.11
Totals:			**5**	**188**		

b. July 2007

Family	Latin Name	Common Name	Occurrence	Total	Mean	SE
Fish:						
Pseudomugilidae	*Pseudomugil signifer*	Common Blue-eye	2	137	1.9	1.87
Mugilidae	*Mugil cephalus*	Sea mullet	2	2	0.03	0.03
Totals:			**2**	**139**		
Invertebrates:						
Caridae	*Palaemon intermedius*	Shrimp	1	9	0.13	0.13

Table 31. Fish and crustaceans collected by seining (9 samples) along the Caboolture River, January 2006. See Figure 7 for seining positions.

Family	Scientific name	Common Name	Occurrence	Total	Mean	SE
Fish:						
Clupeidae	*Herklotsichthys castelnaui*	Southern Herring	4	76	8.44	7.95
Engraulidae	*Engraulis australis*	Australian Anchovy	2	8	0.89	0.68
Ariidae	*Arius graffei*	Blue Catfish	1	7	0.78	0.78
Hemirphampidae	*Hyporhamphus* sp.	Garfish	1	3	0.33	0.33
Platycephalidae	*Platycephalus fuscus*	Dusky Flathead	2	6	0.67	0.55
Ambassidae	*Ambassis marianus*	Ramsay's Glassfish	8	159	17.67	6.25
Pseudomugilidae	*Pseudomugil hybrid sp.*	Blue-eye	1	5	0.56	0.56
Sillaginidae	*Sillago ciliata*	Sand Whiting	2	8	0.89	0.68
	Sillago maculata	Trumpeter Whiting	5	95	10.56	6.47
	Sillago sp.	Unidentified Whiting	2	8	0.89	0.68
Leiognathidae	*Leignathus equula*	Common Ponyfish	5	168	18.67	11.69
Sparidae	*Acanthopagrus australis*	Yellowfin Bream	2	15	1.67	1.13
	Rhabdosargus sarba	Tarwhine	1	1	0.11	0.11
Gerreidae	*Gerres subfasciatus*	Common Silver Belly	6	24	2.67	1.13
Theraponidae	*Terapon jarbua*	Crescent Perch	1	1	0.11	0.11
Lutjanidae	*Lutjanus fulviflamma*	Black-spot Seaperch	1	1	0.11	0.11
Monodactylidae	*Mondactylus argenteus*	Diamond Fish	2	9	1.00	0.78
Scatophagidae	*Selenotoca multifasciata*	Striped Scat	1	1	0.11	0.11
Mugilidae	*Mugil georgii*	Fantail Mullet	5	228	25.33	15.95
Polynemidae	*Polydactylus mutliradiatus*	Gunther's Threadfin Salmon	1	1	0.11	0.11
Callionymidae	*Eocallionymus papilio*	Painted Stinkfish	1	1	0.11	0.11
Eleotridae	*Philypnodon grandiceps*	Flathead Gudgeon	1	1	0.11	0.11
Gobiidae	*Istigobius* sp.	Goby	5	16	1.78	1.00
	Pseudogobius olorum	Blue-spot Goby	1	1	0.11	0.11
	-	Unidentified goby	1	1	0.11	0.11
Tetraodontidae	*Torquigoner pleurosticta*	Banded Toadfish	5	19	2.11	1.29
	Tetractenos hamiltoni	Common Toad	4	24	2.67	1.34
	Torquigener squamicauda	Brush-tail Toadfish	2	15	1.67	1.11
Totals:			**28**	**902**		
Decapod crustaceans:						
Portunidae	*Scylla serrata*	Mud Crab	1	1	0.11	0.11
Sibogidae	*Acetes sibogae*	Sibogid shrimp	4	793	88.11	50.40
Caridae	*Macrobrachium sp.*	Cherabin	1	1	0.11	0.11
Peneidae	*Penaeus sp.*	Prawn	8	119	13.22	9.40
Totals:			**4**	**914**		

Table 32. Analyses of variance of the median grain size of sediments in Channel and Flat sites in the Caboolture River in March 2007. Significant factors are shown in bold. SNK comparisons of Sites within and between Habitats are also shown (p < 0.05).

Taxon/Source	SS	DF	MS	F	P	F versus
Median grain size						
Transform - none						
Cochran's C = 0.3404 (p > 0.05)						
Habitat	0.007	1	0.007	0.460	0.512	Sites(Habitat)
Sites(Habitat)	0.144	10	0.014	18.380	**< 0.001**	Residual
Residual	0.009	12	0.001			
Total	0.160	23				

SNK within Habitats		SNK between Habitats	ns
Channel	S7=S9=S10 < S1=S2=S8		
Flats	S11=S13=S14 < S12=S15=S16		

Table 33. Analyses of Similarities (ANOSIM) of macrobenthic assemblages in Channel and Flat sites in the Caboolture River in March 2007. Significant results are shown in bold, all data transformed to fourth root.

Comparison	R-value	P
Global Test: Channel vs Flats	0.714	**0.001**
Paired tests		
Channel Site 1 vs Flats Site 16	0.677	**0.029**
Channel Site 2 vs Flats Site 15	0.292	0.086
Channel Site 7 vs Flats Site 14	0.667	**0.029**
Channel Site 8 vs Flats Site 13	1.000	**0.029**
Channel Site 9 vs Flats Site 12	0.766	**0.029**
Channel Site 10 vs Flats Site 11	0.875	**0.029**

Table 34. Similarity Percentage Analyses (SIMPER) of macrobenthic assemblages in Channel and Flat habitats in the Caboolture River in March 2007. Cut off for significance 50%, all data transformed to fourth root.

Taxon	Channel Av.Abund	Flats Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oweniidae	0.15	13.88	5.18	1.08	6.82	6.82
Capitellidae	2.78	3.04	4.47	1.18	5.88	12.70
Lucinidae	0.50	6.58	4.19	0.98	5.52	18.22
Lumbrineridae	2.60	0.33	4.10	1.11	5.40	23.62
Galeommatidae	2.05	1.63	3.94	0.97	5.18	28.81
Orbiniidae	0.13	2.08	3.86	0.76	5.08	33.89
Glyceridae	2.70	1.75	3.86	1.10	5.08	38.97
Mactridae	2.50	2.08	3.73	1.00	4.91	43.88
Cirratulidae	1.28	0.00	3.47	0.84	4.56	48.45
Spionidae	1.70	0.38	3.13	0.95	4.12	52.57

Table 35. Analyses of variance of the mean total number of taxa and abundances of taxa contributing 5% or more to dissimilarities between macrobenthic assemblages in Channel and Flat sites in the Caboolture River in March 2007. Significant factors are shown in bold. SNK comparisons of Sites within and between Habitats are also shown (p < 0.05).

a. No of Taxa Transform - Sqrt(X+1) Cochran's C = 0.3136 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	247.521	1	247.521	4.240	0.067	Sites(Habitat)	Within Habitats:	Channel:	S2=S9=S10 < S1=S7=S8
Sites(Habitat)	584.208	10	58.421	4.370	**0.001**	Residual		Flats:	S11=S12=S13=S14=S15=S16
Residual	480.750	36	13.354				Between Habitats:		S13 < S8
Total	1312.479	47							

b. Oweniidae Transform - Ln(X+1) Cochran's C = 0.2967 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	7.456	1	7.456	1.320	0.277	Sites(Habitat)	Within Habitats:	Channel:	S2=S9=S10 < S1=S7=S8
Sites(Habitat)	56.335	10	5.634	8.920	**<0.001**	Residual		Flats:	S11=S12 < S15=S16 < S13=S14
Residual	22.727	36	0.631				Between Habitats:		S7 < S14; S8 < S13
Total	86.518	47							

c. Capitellidae Transform - Sqrt(X+1) Cochran's C = 0.2730 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	1.325	1	1.325	0.440	0.521	Sites(Habitat)	Within Habitats:	Channel:	S1=S2=S7=S8=S9=S10
Sites(Habitat)	29.893	10	2.989	13.470	**<0.001**	Residual		Flats:	S11=S12=S13=S14=S15 < S16
Residual	7.989	36	0.222				Between Habitats:		ns
Total	39.207	47							

d. Lucinidae Transform - Ln(X+1) Cochran's C = 0.2215 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	5.166	1	5.166	1.530	0.244	Sites(Habitat)	Within Habitats:	Channel:	S7=S9=S10 < S1=S2=S3
Sites(Habitat)	33.657	10	3.366	11.220	**<0.001**	Residual		Flats:	S11=S12=S13=S14=S15 < S16
Residual	10.798	36	0.300				Between Habitats:		S13 < S8
Total	49.621	47							

continued…

Table 35 continued

e. Lumbrineridae Transform - Ln(X+1) Cochran's C = 0.3979 (p < 0.01)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	9.500	1	9.500	6.040	**0.034**	Sites(Habitat)	Within Habitats:	Channel:	S7=S8=S9=S10 < S1=S2
Sites(Habitat)	15.742	10	1.574	5.490	**<0.001**	Residual		Flats:	S11=S12=S13=S14=S15=S16
Residual	10.331	36	0.287				Between Habitats:		S16 < S1; S15 < S2
Total	35.574	47							

f. Geleommatidae Transform - None Cochran's C = 0.2823 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	10.083	1	10.083	0.950	0.354	Sites(Habitat)	Within Habitats:	Channel:	S1=S2=S7=S8=S9=S10
Sites(Habitat)	106.583	10	10.658	1.910	0.076	Residual		Flats:	S11=S12=S13=S14=S15=S16
Residual	201.000	36	5.583				Between Habitats:		ns
Total	317.667	47							

g. Orbinidae Transform - Ln(X+1) Cochran's C = 0.4574 (p < 0.01)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	4.006	1	4.006	3.060	0.111	Sites(Habitat)	Within Habitats:	Channel:	S1=S2=S7=S8=S9=S10
Sites(Habitat)	13.075	10	1.308	6.190	**<0.001**	Residual		Flats:	S13=S14=S15=S16 < S11=S12
Residual	7.610	36	0.211				Between Habitats:		S1 < S16
Total	24.691	47							

h. Glyceridae Transform - None Cochran's C = 0.3171 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Oucomes		
Habitat	44.083	1	44.083	1.130	0.313	Sites(Habitat)	Within Habitats:	Channel:	S1=S2=S7=S8=S9=S10
Sites(Habitat)	389.833	10	38.983	5.800	**<0.001**	Residual		Flats:	S11=S12=S13=S15=S16 < S14
Residual	242.000	36	6.722				Between Habitats:		S7 < S14
Total	675.917	47							

Table 36. Analyses of Similarities (ANOSIM) of macrobenthic assemblages in Channel sites in April 2006 and March 2007 in the Caboolture River. Significant results are shown in bold, all data transformed to fourth root.

Comparison	R-value	P
Global Test: April 06 vs March 07	0.641	**0.001**
April Site 12 vs March Site 12	1.000	**0.029**
April Site 13 vs March Site 13	0.438	0.057
April Site 14 vs March Site 14	0.854	**0.029**

Table 37. Similarity Percentage Analyses (SIMPER) of assemblages of benthic invertebrates in Channel sites in April 2006 and March 2007 in the Caboolture River. Cut off for significance 50%, all data transformed to fourth root.

Taxon	April 2006	March 2007				
	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Cirratulidae	0.00	1.54	4.32	1.35	5.71	5.71
Lumbrineridae	0.00	3.50	3.84	1.18	5.07	10.78
Glyceridae	0.83	3.63	3.70	1.33	5.01	15.79
Oweniidae	2.17	2.79	3.46	1.16	4.57	20.36
Mactridae	1.83	1.75	2.94	1.08	3.89	24.25
Galeommatidae	1.75	2.71	2.86	1.10	3.78	28.03
Nemertea	0.83	0.67	2.86	1.17	3.78	31.81
Spionidae	0.83	1.79	2.82	1.03	3.72	35.54
Psammobiidae/Tellinidae	1.00	0.04	2.68	1.04	3.55	39.08
Capitellidae	1.25	2.29	2.67	0.86	3.53	42.61
Sabellidae	1.25	0.54	2.54	1.01	3.36	45.97
Ampharetidae	0.00	1.63	2.41	0.89	3.18	49.15
Magelonidae	0.33	0.79	2.26	0.94	2.98	52.13

Table 38. Analyses of variance of the mean total number of taxa and abundances of taxa contributing 5% or more to dissimilarities between macrobenthic assemblages in Channel sites in the Caboolture River in April 2006 and March 2007. Significant factors are shown in bold. SNK comparisons of Sites between Times are also shown (* p < 0.05; ** p < 0.01; ns = not signficant).

a. Number of Taxa Transform - None Cochran's C = 0.5835 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome			
Times	541.500	1	541.500	15.220	**0.018**	Sites(Times)		Site 12	Site 13	Site 14
Sites(Times)	142.333	4	35.583	0.800	0.544	Sites(Times)	April '06 vs March'07	*	ns	*
Residual	805.500	18	44.750			Residual				
Total	1489.333	23								

b. Cirratulidae Transform - None Cochran's C = 0.4936 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome			
Times	14.260	1	14.260	12.560	**0.024**	Sites(Times)		Site 12	Site 13	Site 14
Sites(Times)	4.542	4	1.135	1.390	0.277	Sites(Times)	April '06 vs March'07	**	*	ns
Residual	14.688	18	0.816			Residual				
Total	33.490	23								

c. Lumbrineridae Transform - Ln(X+1) Cochran's C = 0.5280 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome			
Times	5.713	1	5.713	2.660	0.178	Sites(Times)		Site 12	Site 13	Site 14
Sites(Times)	8.593	4	2.148	12.620	**<0.001**	Sites(Times)	April '06 vs March'07	**	ns	ns
Residual	3.064	18	0.170			Residual				
Total	17.370	23								

d. Glyceridae Transform - None Cochran's C = 0.3605 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome			
Times	46.760	1	46.760	2.040	0.227	Sites(Times)		Site 12	Site 13	Site 14
Sites(Times)	91.792	4	22.948	8.270	**0.001**	Sites(Times)	April '06 vs March'07	**	ns	*
Residual	49.938	18	2.774			Residual				
Total	188.490	23								

Table 39. List of fish and invertebrate species, with frequency of occurrence and total numbers, caught by seining in and adjacent to the navigational channel of the Caboolture River in March 2007.

Family	Scientific name	Common name	No. of Occurrences	Total
Fish:				
Clupeidae	*Hyperlophus vittatus*	Sandy sprat	9	158
	Herklotsichys castelnaui	Southern herring	16	364
Engraulidae	*Engraulis australis*	Australian anchovy	16	386
	Thrissina aestuaria	Anchovy	2	19
Hemirhamphidae	*Hyporhamphus australis*	Sea garfish	13	112
Atherinidae	*Pranesus ogilbyi*	Hardyhead	1	11
Platycephalidae	*Platycephalus fuscus*	Dusky flathead	1	1
	Platycephalus sp.	Unidentified flathead	4	5
Apogonidae	*Apogon atripes*	Soldier fish	1	1
Sillaginidae	*Sillago maculata*	Trumpeter whiting	20	182
Pomatomidae	*Pomatomus saltatrix*	Tailor	3	3
Carangidae	*Scomberoides lysan*	Queenfish	1	2
	Caranx sp.	Trevally	1	1
Leiognathidae	*Leignathus equula*	Common pony fish	10	326
Sparidae	*Rhabdosargus sarba*	Tarwhine	1	1
Gerreidae	*Gerres subfasciatus*	Silver biddy	15	188
Monodactylidae	*Mondactylus argenteus*	Diamond fish	1	1
Scatophagidae	*Selenotoca multifasciata*	Striped Scat	1	2
Mugilidae	-	Unidentified mullet	3	9
Polynemidae	*Polydactylus* sp.	Threadfin salmon	1	1
Callionymidae	*Eocallionymus papilio*	Painted Stinkfish	7	12
Gobiidae	*Istigobius* sp.	Unidentified goby	6	10
Siganidae	*Siganus fuscescens*	Black spinefoot	5	7
Bothidae	*Pseudorhombus jenynsii*	Small-tooth flounder	3	3
	Pseudorhombus arsius	Large-tooth flounder	1	1
Soleidae	*Synaptura nigra*	Black sole	2	2
Tetraodontidae	*Tetractenos hamiltoni*	Hamilton's toadfish	14	86
	Tetractenos glaber	Smooth toadfish	4	12
Totals:			**28**	**1906**
	Invertebrates:			
Portunidae	*Portunus pelagicus*	Sand crab	3	6
Sibogidae	*Acetes sibogae*	Sibogid shrimp	8	62
Peneidae	*Penaeus sp.*	Prawn	9	12
Caridae	-	Carid shrimp sp. 1	1	2
	-	Carid shrimp sp. 2	10	14
Totals:			**5**	**96**

Table 40. Mean length and length range of fish and invertebrates caught in Channel and tidal flats sites in March 2007 in the Caboolture River.

Species	Habitat	Number	Mean length (mm)	SE	Range (mm)
Platycephalus sp.	Channel	4	84.25	10.94	55 - 108
Hyporhamphus australis	Channel	27	69.81	3.94	49 - 127
	Flats	48	89.10	4.15	42 - 156
Mugilidae	Channel	9	53.67	17.67	6 - 127
Gerres subfasciatus	Channel	52	74.17	4.26	30 - 143
	Flats	40	65.32	3.71	37 - 153
Scomberoides lysan	Flats	5	74.00	10.22	50 - 110
Pomatomus saltatrix	Channel	3	100.33	34.17	32 - 135
Sillago maculata	Channel	55	72.55	4.30	22 - 134
	Flats	64	128.00	68.92	29 - 128
Unid. Flounder	Channel	3	118.67	50.75	63 - 220
Portunus pelagicus	Channel	5	51.20	9.52	32 - 82
	Flats	2	48.00	2.00	46 - 50

Table 41. Similarity Percentage Analyses (SIMPER) of fish assemblages in Channel and Flat habitats in the Caboolture River in March 2007. Cut off for significance 90%, all data transformed to fourth root.

Taxon	Channel	Flats				
	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Engraulis australis	28.75	3.42	9.76	0.86	14.21	14.21
Herklotsichys castelnaui	22.08	8.25	8.65	1.13	12.60	26.81
Leignathus equula	18.08	9.08	7.13	0.95	10.37	37.18
Gerres subfasciatus	7.08	8.58	6.19	1.30	9.02	46.20
Hyperlophus vittatus	7.92	5.25	5.99	0.82	8.73	54.92
Garfish sp.*	2.42	6.92	5.79	0.92	8.43	63.35
Sillago maculata	7.92	7.33	5.67	1.22	8.26	71.61
Tetractenos hamiltoni	5.92	1.25	5.06	0.95	7.36	78.97
Repomucenus calcaratus	0.83	0.17	2.08	0.91	3.03	82.00
Istigobius sp.	1.00	0.00	1.84	0.61	2.68	84.68
Platycephalus sp.	0.33	0.50	1.46	0.73	2.13	86.81
Siganus nebulosus	0.33	0.08	1.33	0.55	1.93	88.74

* *Hyporhamphus australis* and
Arrhamphus sclerolepis

Table 42. Analyses of variance of the mean total number of fish taxa and abundances of fish contributing 5% or more to dissimilarities between assemblages in Channel and Flat sites in the Caboolture River in March 2007. Significant factors are shown in bold. SNK comparisons of Sites within and between Habitats are also shown ($p < 0.05$).

a. No. of Taxa

Transform - Sqrt(X+1) Cochran's C = 0.2727 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	54.000	1	54.000	3.900	0.096	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	83.167	6	13.861	2.330	0.083	Residual	SNK between Habitats		ns
Residual	95.333	16	5.958						
Total	232.500	23							

b. Engraulis australis Transform - Ln(X+1) Cochran's C = 0.3865 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	5.187	1	5.187	2.230	0.186	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	13.978	6	2.330	1.200	0.358	Residual	SNK between Habitats		ns
Residual	31.174	16	1.948						
Total	50.338	23							

c. Herklotsichys castelnaui Transform - None Cochran's C = 0.4303 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	486.000	1	486.000	0.550	0.486	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	5283.167	6	880.528	0.870	0.536	Residual	SNK between Habitats		ns
Residual	16156.667	16	1009.792						
Total	21925.833	23							

d. Leignathus equula Transform - Sqrt (X+1) Cochran's C = 0.4371 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	4.233	1	4.233	1.520	0.264	Sites(Habitat)	SNK within Habitats	Channel	S1=S3=S4 < S2
Sites(Habitat)	16.708	6	2.785	4.850	**0.005**	Residual		Flats	ns
Residual	9.178	16	0.574				SNK between Habitats		ns
Total	30.118	23							

e. Gerres subfasciatus Transform - Sqrt(X+1) Cochran's C = 0.2640 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	2.164	1	2.164	0.740	0.422	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	17.482	6	2.914	2.280	0.088	Residual	SNK between Habitats		ns
Residual	20.454	16	1.278						
Total	40.099	23							

continued…

Table 42 continued

f. Hyperlophus vittatus Transform - Ln (X+1) Cochran's C = 0.4006 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	1.769	1	1.769	0.590	0.471	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	17.915	6	2.986	2.110	0.110	Residual	SNK between Habitats		ns
Residual	22.679	16	1.418						
Total	42.363	23							

g. Garfish spp. (*Hyporhamphus australis* & *Arrhamphus sclerolepis*)
Transform - Sqrt (X+1) Cochran's C = 0.4258 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	0.002	1	0.002	0.000	0.981	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	22.179	6	3.697	1.100	0.404	Residual	SNK between Habitats		ns
Residual	53.761	16	3.360						
Total	75.943	23							

h. Sillago maculata Transform - Ln (X+1) Cochran's C = 0.3143 (p > 0.05)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	1.174	1	1.174	0.180	0.683	Sites(Habitat)	SNK within Habitats	Channel	S1=S3=S4 < S2
Sites(Habitat)	38.264	6	6.377	6.710	**0.001**	Residual		Flats	S2=S3=S4 < S1
Residual	15.210	16	0.951						
Total	54.648	23					SNK between Habitats		ns

i. Tetractenos hamiltoni Transform - Sqrt (X+1) Cochran's C = 0.7744 (p < 0.01)

Source	SS	DF	MS	F	P	F versus	SNK Outcome		
Habitat	0.9134	1	0.9134	5.41	0.0589	Sites(Habitat)	SNK within Habitats		ns
Sites(Habitat)	1.0127	6	0.1688	0.65	0.6901	Residual	SNK between Habitats		ns
Residual	4.1561	16	0.2598						
Total	6.0822	23							

Table 43. Summary and analysis of Aquatic Environmental Values.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Water & Sediment Quality	Health of Caboolture River estuary	1) Extent of estuary truncated by weir; 2) Reduced riverine input; 3) Discharges from Municipal Waste water Treatment Plants (WWTP's); 4) Bank erosion with potential increases in turbidity; 5) Other human activities (e.g. existing marina).	1) High levels of nutrients; 2) Potential erosion; 3) Ecological impacts of weir	Low value due to 1) Poor health; 2) Limited connectivity with upper river	1) Use best practice to ensure NEBP does not increase problems; 2) Need to ensure development does not interfere with tidal & flooding processes; 3) Significant opportunities for re-use of treated waste water to improve water quality of the estuary; 4) Need to monitor & manage water quality in marina basin, including antifouling leachate..
	Acid Sulphate Soils	Low-lying land with acid-generating potential.	1) Release of acid soils can cause fish and invertebrate kills; 2) Flow on effects for biodiversity and fishing amenity - Risk factor for any developments that lead to disturbance of acid soils.	Potential for high ecological and economic cost.	1) Low-lying lands on project site contain acid soils; 2) Treatment of acid soils required as part of cut and fill activities; 2) On-going management of all dredging and on-site construction activities.
	Coastal Algal Blooms	Blooms of Lyngbya in Deception Bay (see below)	1) Blooms becoming more frequent in Deception Bay; 2) Blooms triggered and/or sustained by high levels of nutrients (P, N) and micronutrients (Fe); 3) Potential to affect the value of Deception Bay Fish Habitat Area; 4) potential impacts on human health; 5) Effects may potentially worsen by disturbance of acid soils.	Current high economic and ecological cost.	1) Significant opportunities to reduce nutrients through re-use programme; 2) Use of best practice to ensure NEBP does not increase problems (including management of acid soils).
Aquatic Habitats	River channel (unvegetated)	Subtidal sections of river relatively deep between weir and just downstream of King John Creek; then becomes shallow with limited navigability to Deception Bay.	1) Potential build up of contaminants in sediments; 2) Stratification with low levels of dissolved oxygen recorded near river bed; 3) Shallowing of navigational channel causing changes to habitat and presenting a hazard to boat operators.	1) Comprises extensive habitat within the Caboolture River estuary, much of which is upstream of NEBP project site; 2) Ecological function not well understood, but likely to be important in terms of secondary production, storage of nutrients, etc.	1) Small entrance channel to be created into marina basin, no other dredging required upstream of existing navigation channel; 2) Requirement to dredge downstream for navigation - beneficial for marina patrons and other users; 3) Dredging should minimise disturbance of habitat but would caused a temporary impact on benthic productivity; 4) Disposal and treatment of dredge spoil.

Continued…

Table 43, continued.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
	River Banks (unvegetated)	1) Upstream of King John Creek river banks generally steep; 2) Often show extensive development, especially upstream of project site and on opposite bank to site.	1) Unregulated development and use; 2) Erosion caused by unregulated development and cattle grazing.	Extensive erosion probably adds to water quality issues.	1) Loss of small section of river bank would not represent a large loss of ecological value; 2) NEBP development needs to ensure creation of entrance to marina basin does not exacerbate erosion issues; 3) Boats traveling to and from marina must adhere to speed signs and stay within navigational channel.
	River Flats (unvegetated)	1) Extensive flats in downstream areas; used by wading birds and fish moving up from the channel with the flood tide.	None identified	High environmental value	1) Dredging plan needs to ensure minimal disturbance to this habitat; 2) no wash zones should apply for vessels traveling adjacent to flats.
	Tidal creeks	Numerous tidal creeks flow into the Caboolture R. Natural & artificial creeks on project site - often very short. Some creeks (inc. Raff Creek have sections within Fish Habitat Area).	1) Presence of pest species, particularly mosquito fish; 2) Potential to be affected by development.	Low to moderate - used as habitat by juvenile fishes, but some creeks degraded &/or have mosquito fish.	1) Minimal disturbance to Raff Creek and other creeks and channels outside the marina basin; 2) large potential for rehabilitation/improvement by increasing tidal flushing.
	Mangroves	1) 3 species identified in Caboolture R.; 2) Most mangroves occur downstream of project site; 3) NEBP contains approximately 18.6 ha mangroves, with 0.83 ha that would be removed by the marina basin; 3) some mangroves on project site degraded by previous farming practices.	1) potential loss due to development; 2) Small potential for erosion along Caboolture River (generally protected by peg roots that consolidate sediments).	High value (primary production & fish habitat), particularly in terms of large areas downstream of NEBP project site.	1) Minimise disturbance during construction; 2) ensure flood mitigation measures do not lead to erosion of mangroves; 3) Large potential for rehabilitation/improvement by increasing tidal flushing and planting; 4) Large potential for nature walk through at least one area containing mangroves (and saltmarshes).

Continued…

Table 43, continued.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
	Saltmarshes	1) 4 species identified in Caboolture R.; 2) most saltmarshes occur downstream of project site; 3) NEBP contains approximately 7 ha saltmarshes, with 0.28 ha that would be removed by marina basin.	1) potential loss due to development; 2) potential for erosion along Caboolture River.	High value, particularly in large areas downstream of NEBP project site.	As per mangroves.
	Seagrasses	1) None observed in Caboolture River; 2) None observed in Deception Bay near entrance to river, with the exception of one small patch identified from the air that may have been seagrasses.	Extensive beds once occurred in Deception Bay, potential for recovery may be affected by Lyngbya blooms.	Low to none, given lack of seagrasses in Caboolture River.	1) Currently of no concern; 2) Future recovery of seagrasses may require adjustments to management of vessel movements or footprint and methods of maintenance dredging.
Benthic diversity		1) Defined as invertebrates living in soft sediments in intertidal and subtidal parts of the Caboolture River and tidal creeks; 2) Important source of food for larger invertebrates, fish and birds; 3) Good indicator of biodiversity; 4) Good indicator of estuarine health.	Impacted by a range of human activities, including the weir, discharges from WWTPs, prawn trawling and erosion of river banks.	1) Subtidal habitat - low to moderate value - evidence of large spatial variability along the river and temporal variability in lower reaches; 2) River banks - low value; 3) River flats in downstream areas - high value.	1) Creation of entrance to marina basin - short section of river bank, low value habitat; 2) Erosion due to boat wash, requires strict management; 3) Capital dredging of navigational channel - loss of benthos with likely rapid recover, but on going disturbance due to maintenance dredging; 4) River flats - not to be dredged.
Fish & Decapods		Moderate diversity in river, particularly lower sections - comprises a variety of species that include fish, prawns and crabs targeted by fishers.	1) Lyngbya blooms may devalue status of Fish Habitat Area; 2) Ongoing poor ecological health due to high nutrient levels from WWTP's.	1) Moderate to high in river; 2) Low to moderate in tidal creeks .	1) Potential disturbance of acid soils; 2) Disturbance to tidal creeks on site; 3) Temporary loss of benthic productivity (hence food source) during capital dredging; 4) Potential for beneficial creation of habitat on site in marina basin and by rehabilitation of wetlands; 5) Potential for improvement to ecological health by re-use of treated effluent currently discharged into the river.

Continued…

Table 43, continued.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Conservation Issues	Whales	Baleen and toothed whales occur in coastal waters and eastern parts of Moreton Bay	General conservation concerns, concerns related to boat strike, disturbance.	1) Low risk with respect to Caboolture River; 2) Low to moderate risk with respect to Deception Bay.	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in coastal & Moreton Bay waters.
	Dolphins	At least 3 species may occur in Deception Bay and extending into the Caboolture River.	General conservation concerns, concerns related to boat strike, disturbance.	1) Low to moderate risk with respect to Caboolture River; 2) low to moderate risk with respect to Deception Bay.	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in coastal and Moreton Bay waters.
	Dugong	1) Population in Moreton Bay; 2) Feed on seagrasses; 3) Small occurrence in Deception Bay & Caboolture River.	General conservation concerns, concerns related to boat strike, disturbance.	Low risk	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in Moreton Bay waters.
	Turtles	1) Several species may occur in Moreton Bay; 2) no nesting likely in Caboolture River; 3) no seagrasses, therefore green turtles not likely to feed in the river.	General conservation concerns, concerns related to boat strike, disturbance.	Low risk	1) Management of boat speeds in Caboolture River; 2) Education of marina patrons with respect to activities in Moreton Bay waters.
	Fishes	Scheduled species not recorded in Caboolture River and habitat unsuitable most scheduled species - possible exception honey blue-eye.	1) Alteration of habitat; 2) competition with pest species such as mosquito fish.	Low risk	1) Loss of a small amount of creek habitat due to marina basin; 2) conservation and restoration of other creeks on project site to compensate for this loss.
	Deception Bay Fish Habitat Area (FHA-013)	FHA extends from Deception Bay to Caboolture Weir and into tidal creeks but does not include designated navigation channels.	1) Poor ecological health of Caboolture River; 2) Effects of Lyngbya blooms; 3) Existing habitat disturbance (e.g. 4WD damage; rubbish dumping).	Currently low to moderate, potential to be of high value due to numerous aquatic habitats presence in FHA.	1) Minimal disturbance to tidal areas on project site; 2) Ensure minimal disturbance outside navigation channel during capital dredging; 3) Best practice management in construction & operation; 4) Opportunities to participate in and assist with management of fish habitat.
	Moreton Bay Marine Park (MBMP)	1) MBMP contains Deception Bay and extends into the Caboolture River; 2) special consideration in terms of the MBMP in terms of a large range of human activities.	1) Broad range of issues confronting MBMP; 2) Deception Bay & Caboolture River - Lyngbya, coastal development, fishing.	Very high value, given large population & increasing usage of the resources & amenity of Moreton Bay.	1) Need to ensure the proposed development dose not adversely affect the park values; 2) Legislative requirements in respect of types of development; 3) Opportunities to improve ecological health within the park.

Continued…

Table 43, continued.

Key Environmental Value	Sub-component	Description	Current concerns	Evaluation & cost issues	Key Issues for the NEBP proposal
Pest Species	Lyngbya	Naturally-occurring blue green alga (*Lyngbya majuscula*) that can exhibit large blooms, particularly during warmer months.	See above	See above	See above
	Mosquito fish	Small alien species (*Gambusia holbrooki*) introduced from Central America. Live-bearer able to spawn several times a year.	Competition with native species in tidal creeks.	May diminish value of tidal creeks as nursery habitat for native species.	Difficult to control, but should ensure adequate flushing of any restored tidal creeks on project site.
Fisheries amenity	Recreational fishing	Anglers fish from boats throughout the estuary of the Caboolture River and from several shore-based areas.	1) Diminished ecological health of Caboolture River; 2) "competition" with commercial fishers; 3) potential loss of access for shore-based fishers.	High recreational value due to ready boat access, range of fish, crabs & prawns and large human population in the region	1) Significant opportunities to improve shore-based access; 2) importance of appropriate management of boats using the marina.
	Commercial fishing	Limited prawn trawling and mesh netting in the river.	Diminished ecological health of Caboolture River; 2) "competition" with recreational fishers and boaters.	Moderate value	Importance of appropriate management of boats using the marina.

FIGURES

Figure 39. Mean abundance of *Leignathus equula* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

Figure 40. Mean abundance of *Gerres subfasciatus* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

Figure 41. Mean abundance of *Hyperlophus vittatus* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007

Figure 42. Mean abundance of garfish at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

Figure 43. Mean abundance of *Sillago maculata* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

Figure 44. Mean abundance of *Tetractenos hamiltoni* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

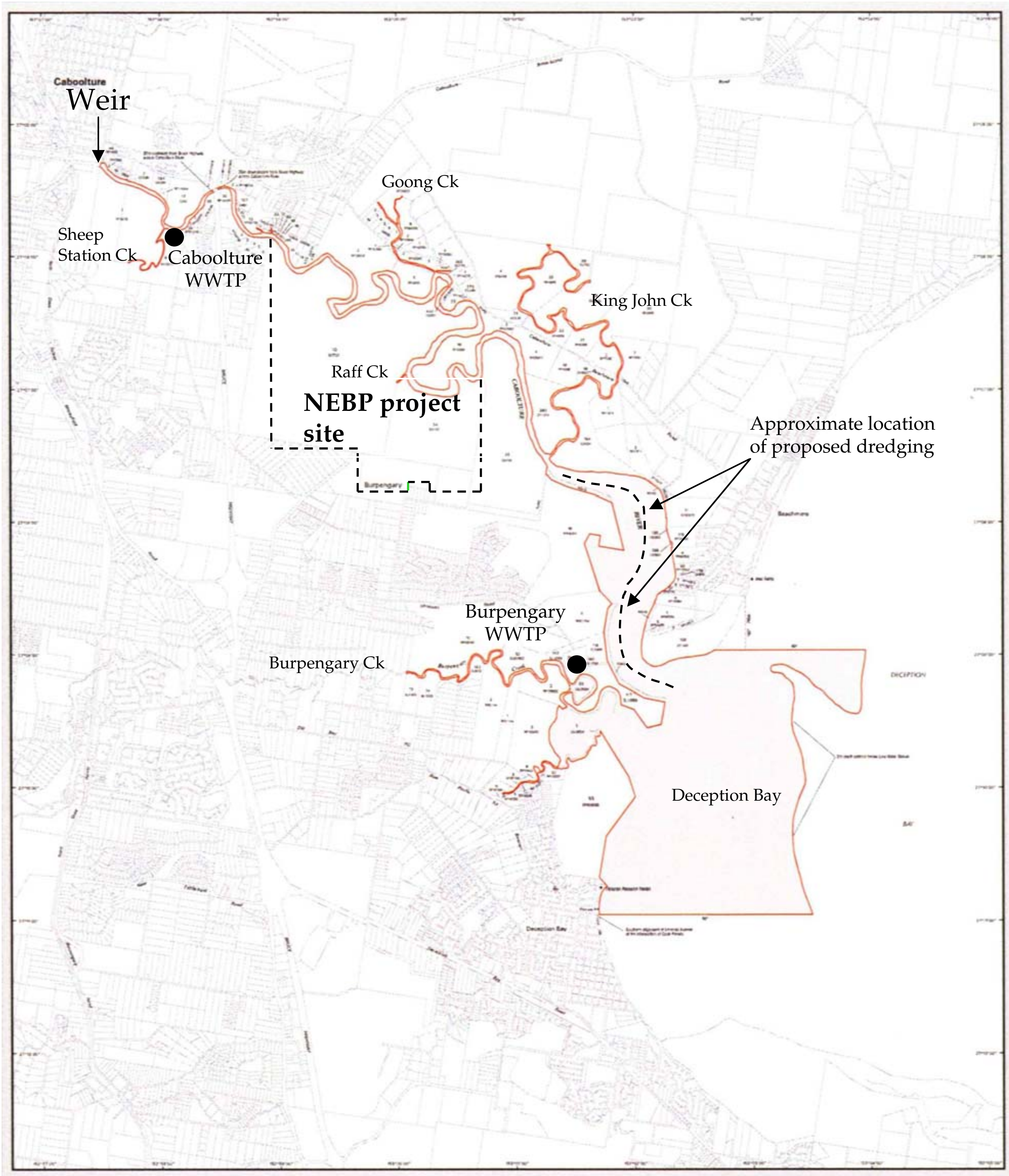


Figure 1. Deception Bay Fish Habitat Area (FHA – 013) showing outer boundary (red line) with approximate boundary of the project site and proposed navigational dredging. Also shown are major creeks flowing into the Caboolture River and the two waste water treatment plants that discharge into or near the Caboolture River. Source of base map & FHA boundary: Qld DPI&F Website.

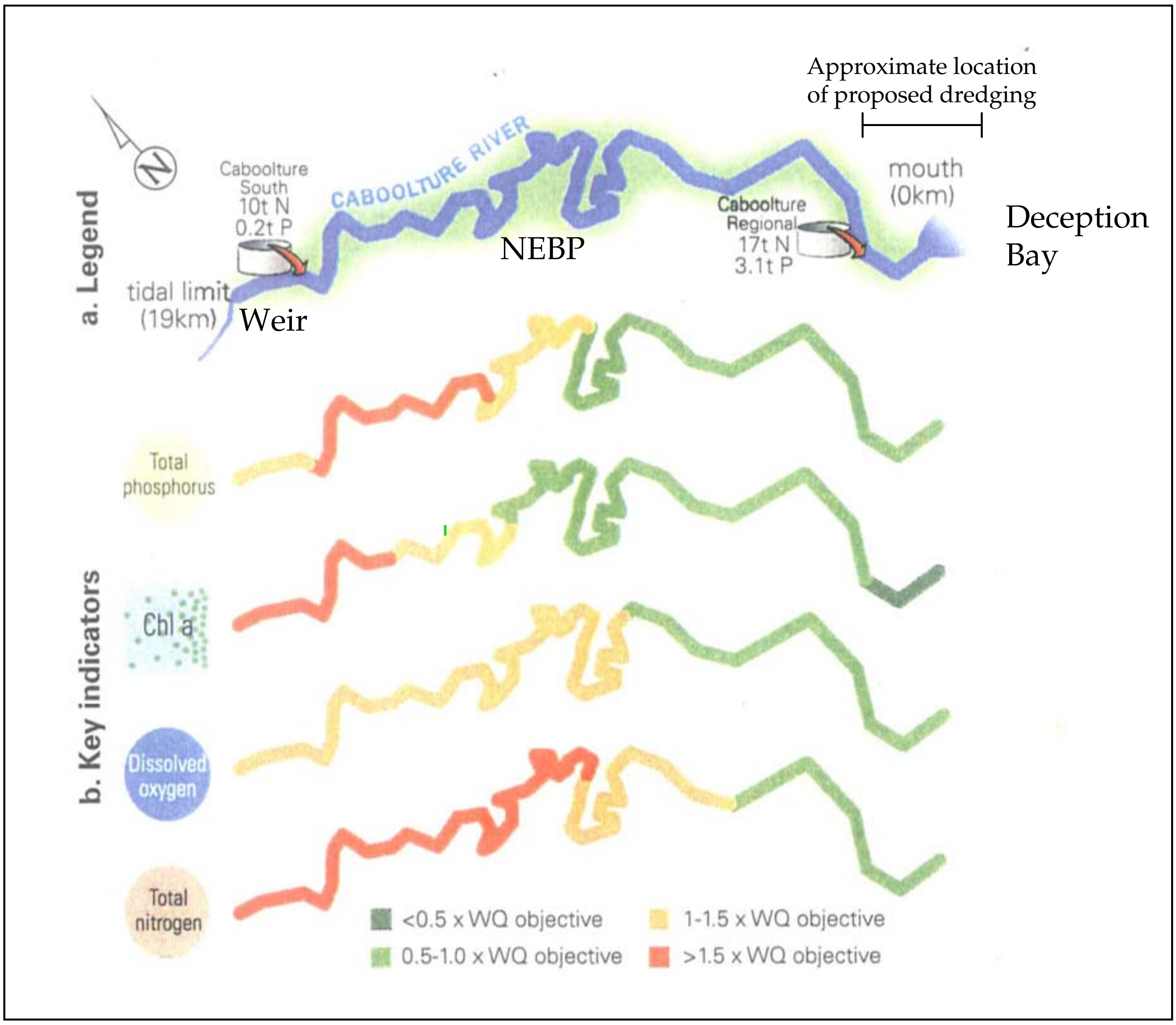
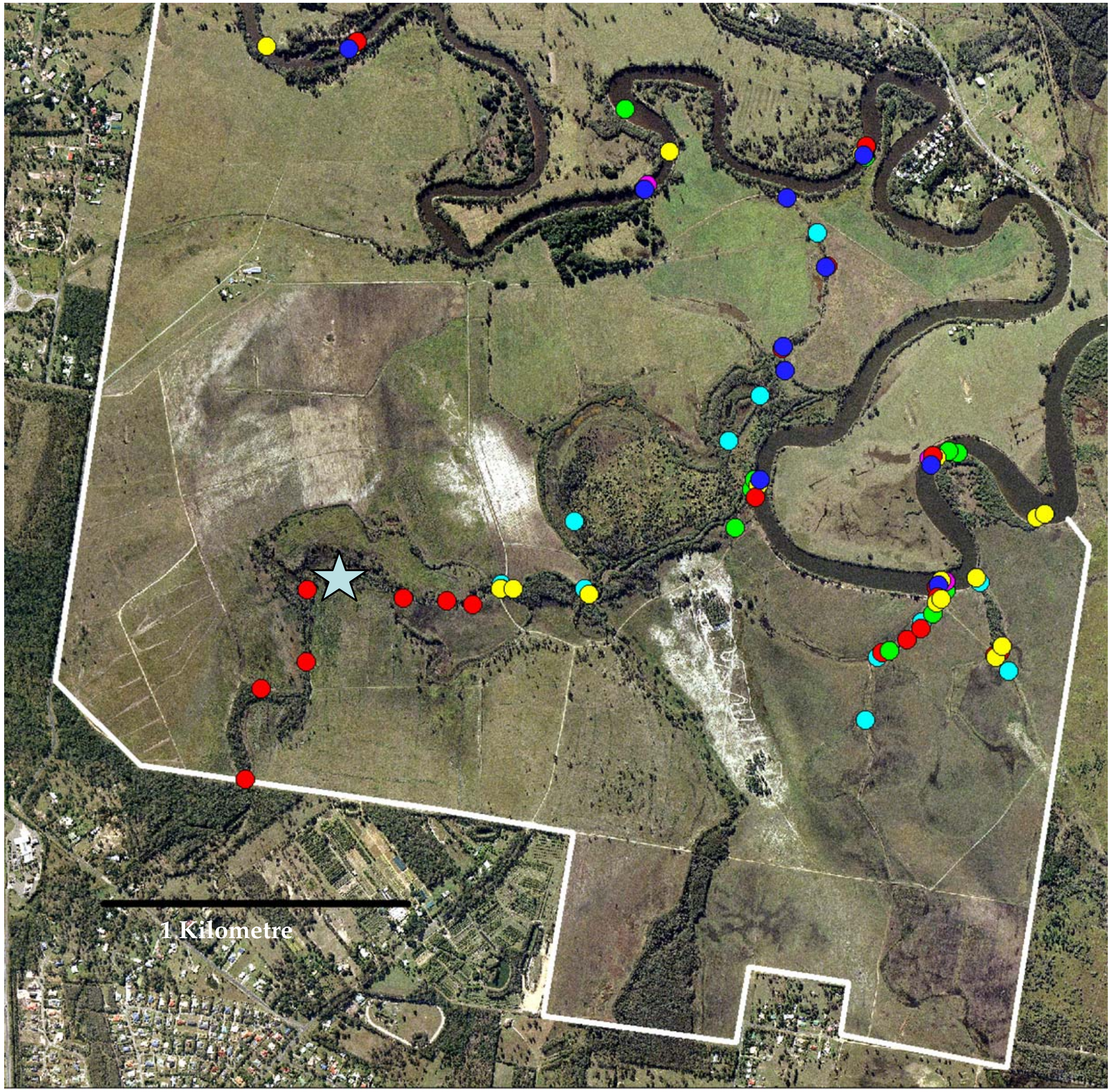


Figure 2. Spatial pattern of water quality in the estuary of the Caboolture River showing stream schematic with total annual loads from WWTPs and compliance with water quality objectives for key indicators, July 2005 – June 2006. Source of schematic: EHMP (2007).

Figure 3. Location of water quality sites 1 – 14 (Yellow dots) sampled in December 2005 and in January, April and August 2006. Red dots indicate sites where benthos and sediment were also sampled in April 2006. White lines indicate site boundary.



Green = March 2005

Red = April 2006

Dark Blue = August 2006

Purple = December 2005

Yellow = January 2006

Light Blue = July 2007

Figure 4. Location of water quality sampling sites within the project site. Blue star shows approximate limit of tidal penetration into Raff Creek as suggested by salinity measures.

Figure 5. Location of Riverbank benthos sampling sites (August 2006).

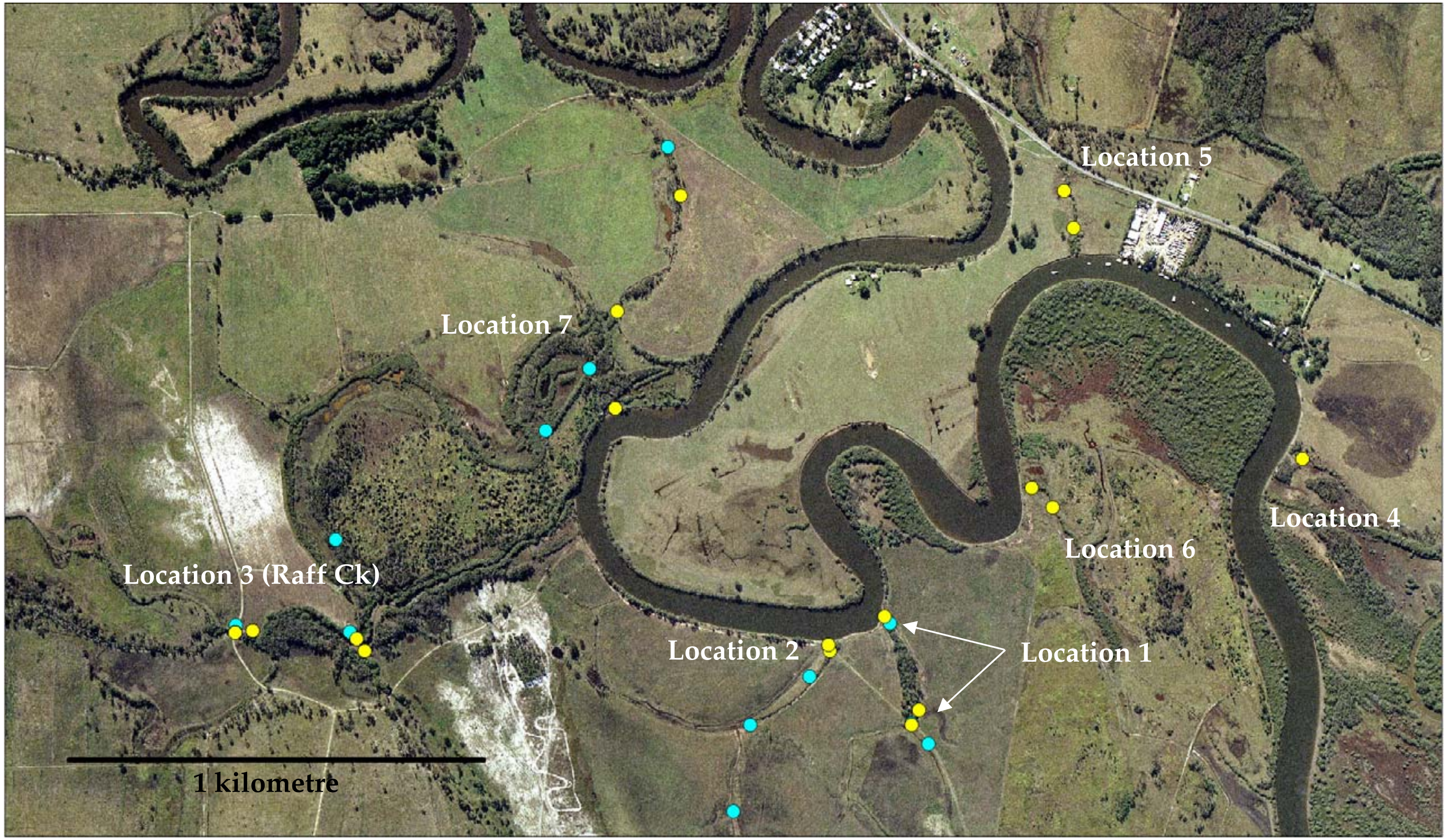


Figure 6. Location of bait trap sites sampled in tidal creeks entering the Caboolture River in January 2006 (yellow) and July 2007 (blue).

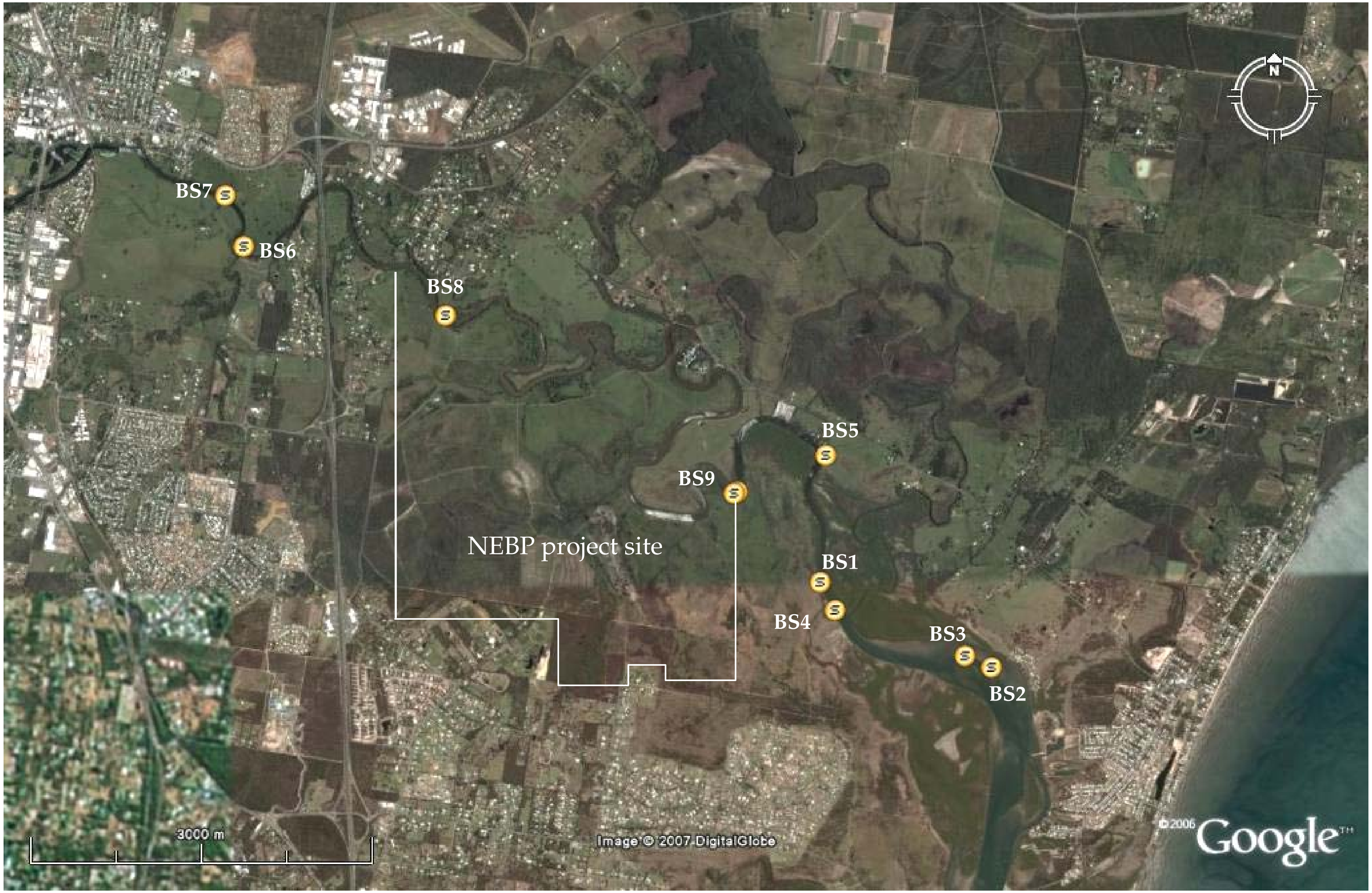


Figure 7. Location of seine net sites sampled in the Caboolture River in January 2006.

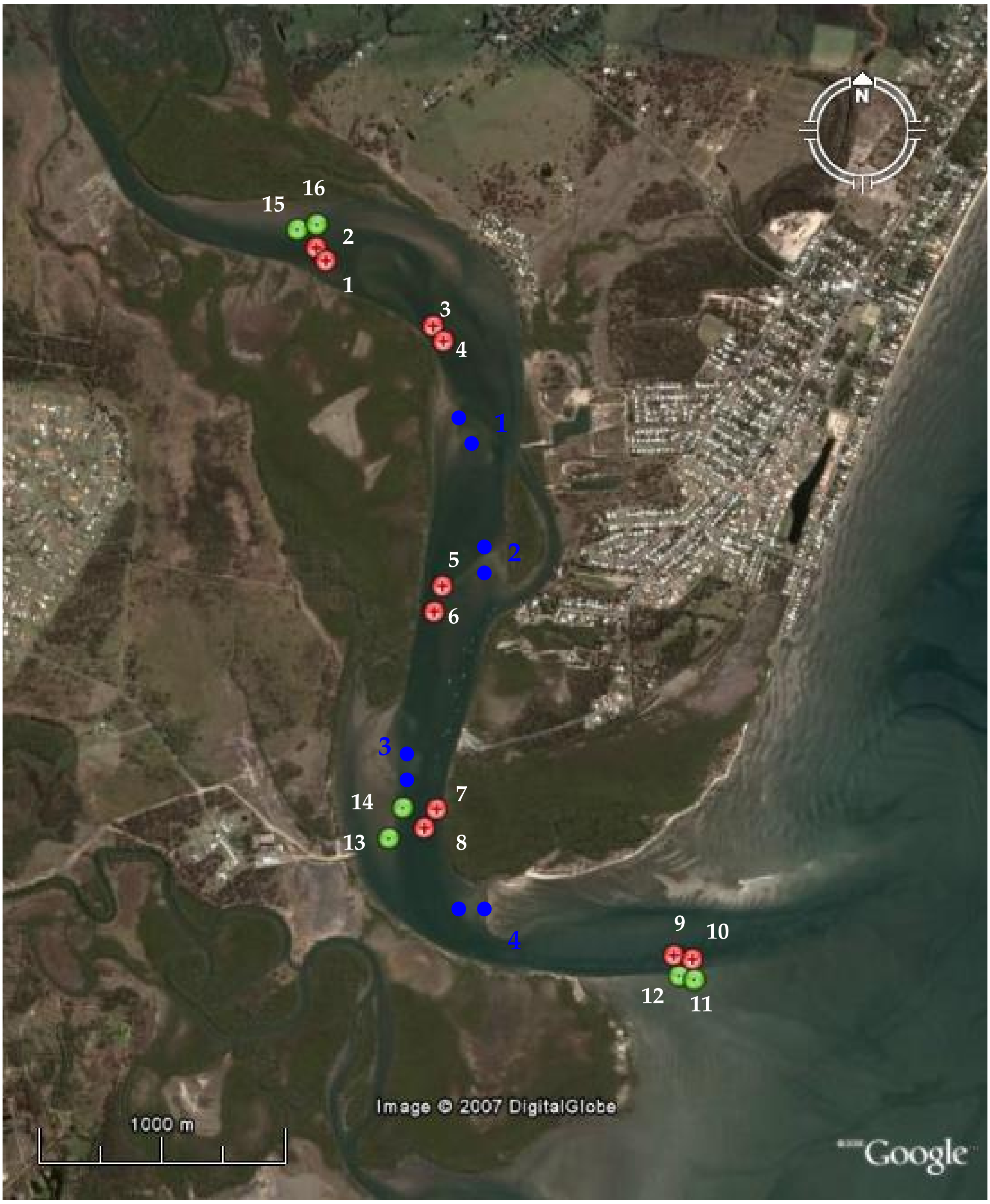


Figure 8. Position of Channel (red) and Flats (green) benthos and fish (blue) sampling locations in the Caboolture River in March 2007.

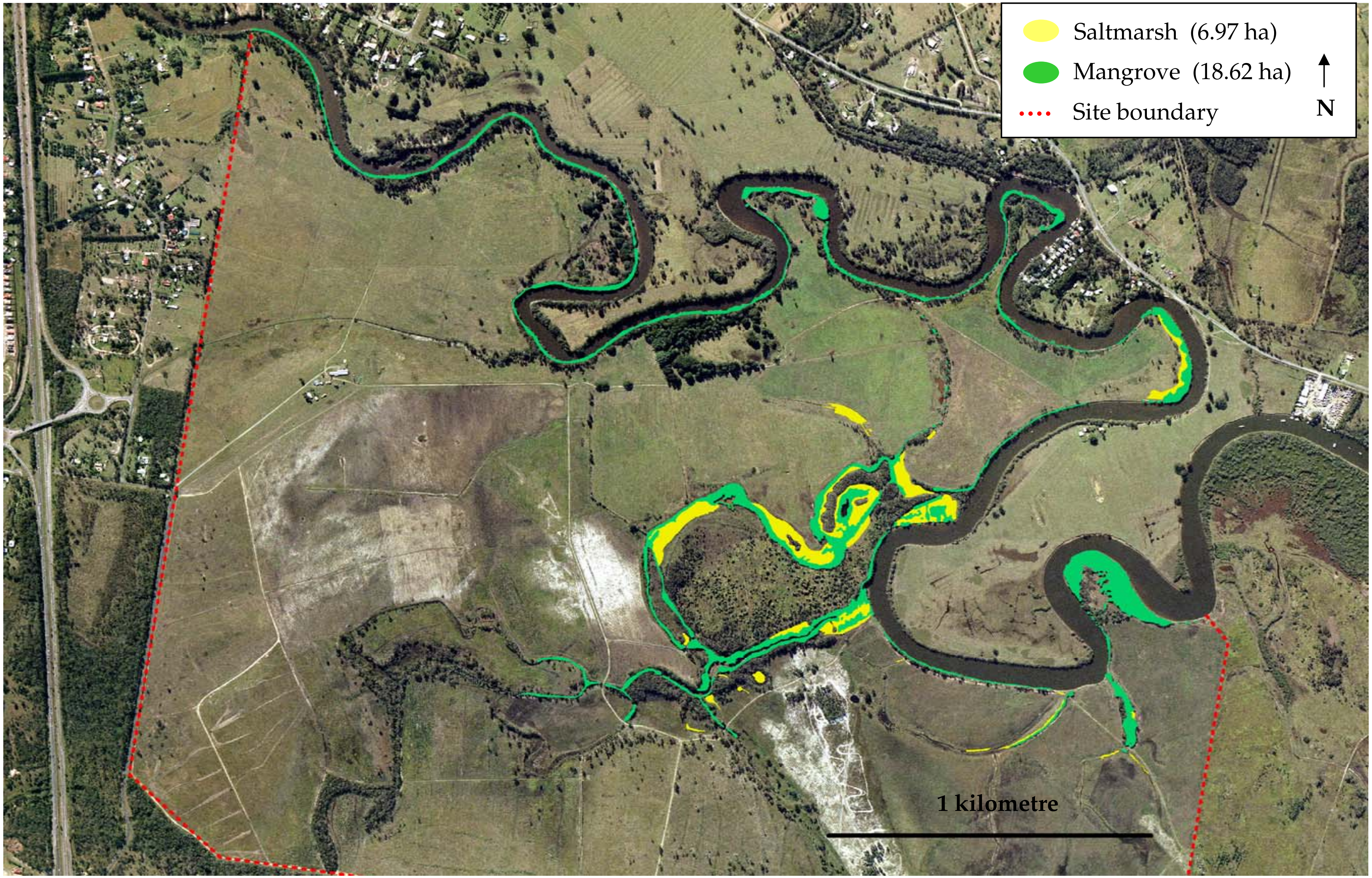


Figure 9. Distribution and extent of marine plants within the NEBP project site.

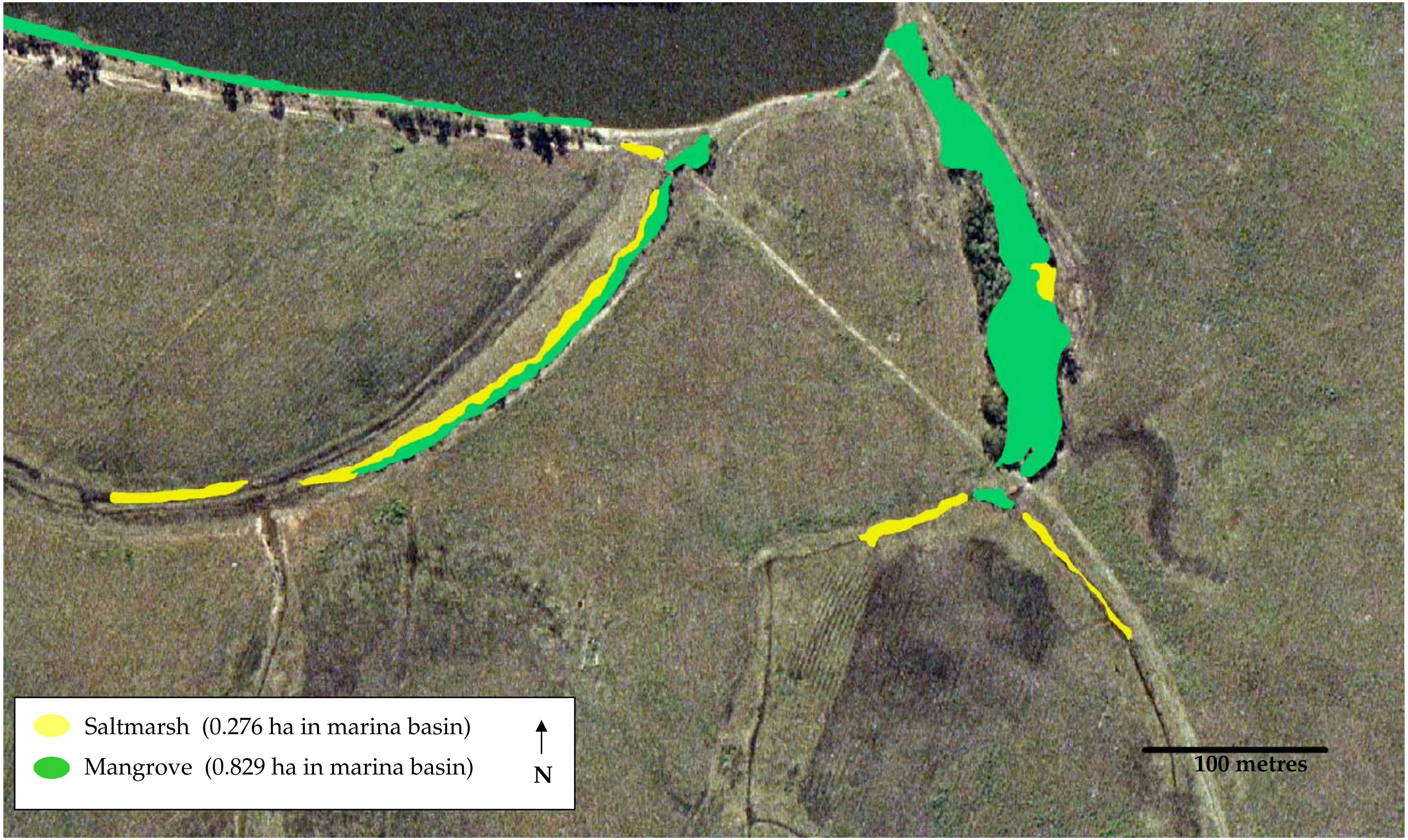


Figure 10. Distribution and extent of marine plants in and around the proposed marina basin.

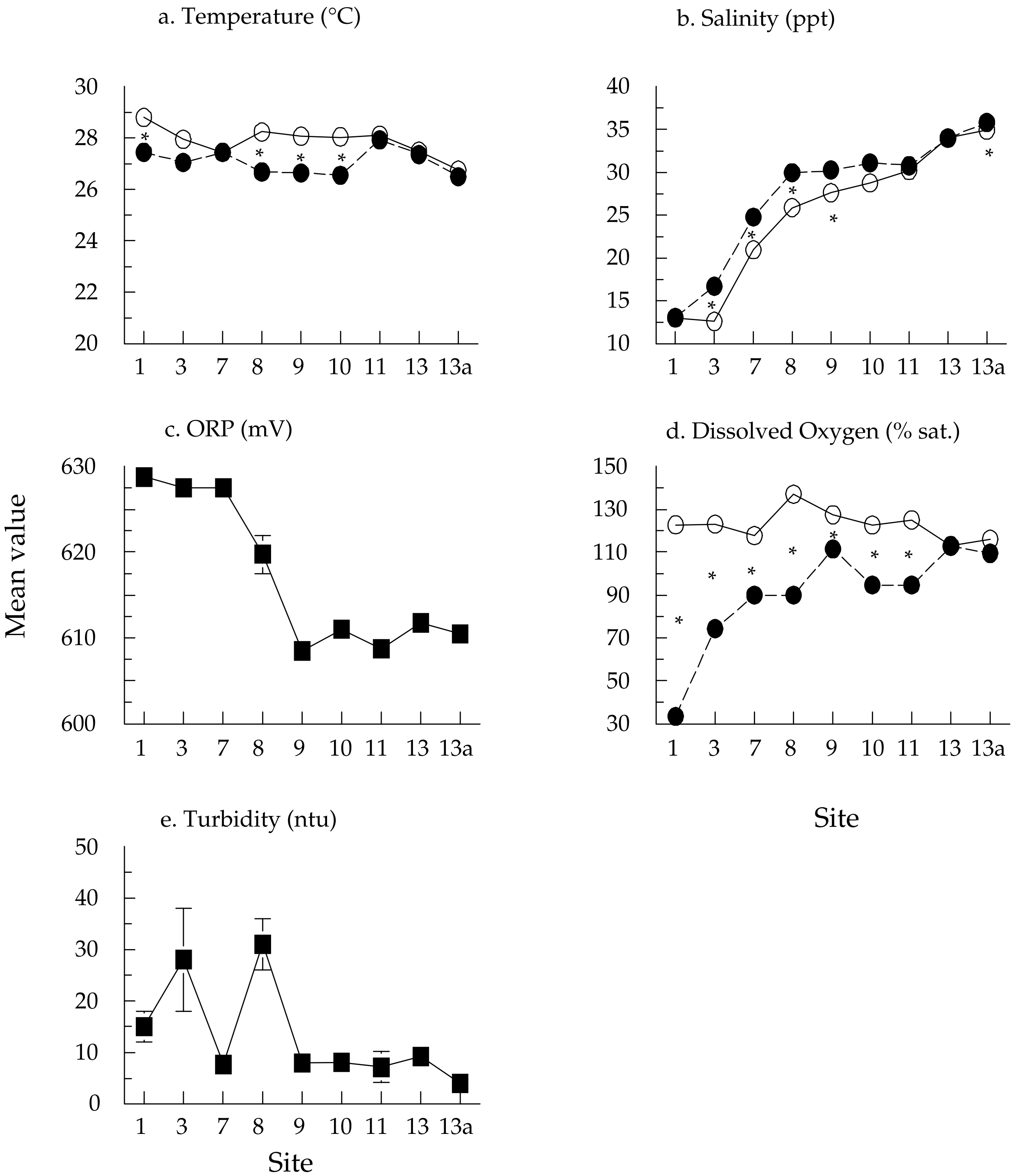


Figure 11. Mean value (± 1 SE) of water quality indicators sampled in the Caboolture River, 19/3/05. Sites extend downstream from the weir (Site 1) to opposite the Beachmere boat ramp (Site 13a). Sites 7-10 are adjacent to the NEBP project site. Open and closed circles = water surface and bottom, respectively (n = 2); closed squares = surface & bottom pooled (*n* = 4). Significant differences between depths (SNK tests) shown by asterisks.

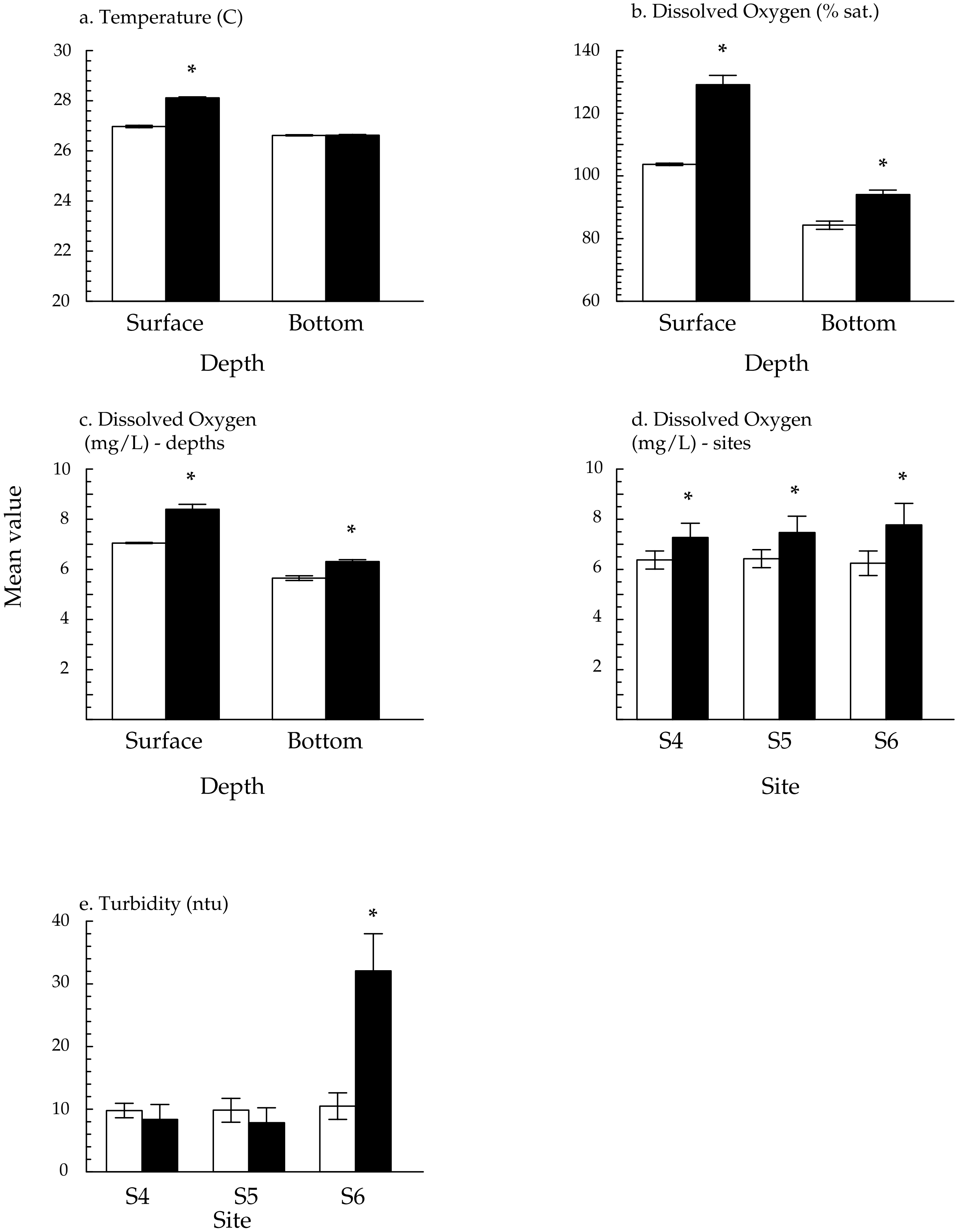


Figure 12. Mean value (± 1 SE) of water quality indicators sampled in the Caboolture River over 2 times (morning and afternoon) at 3 sites adjacent to the NEBP project site (S4 – S6) on 19/3/05. Open bars = morning; closed bars = afternoon (*n* = 6). Significant differences between times (SNK tests) shown by asterisks.

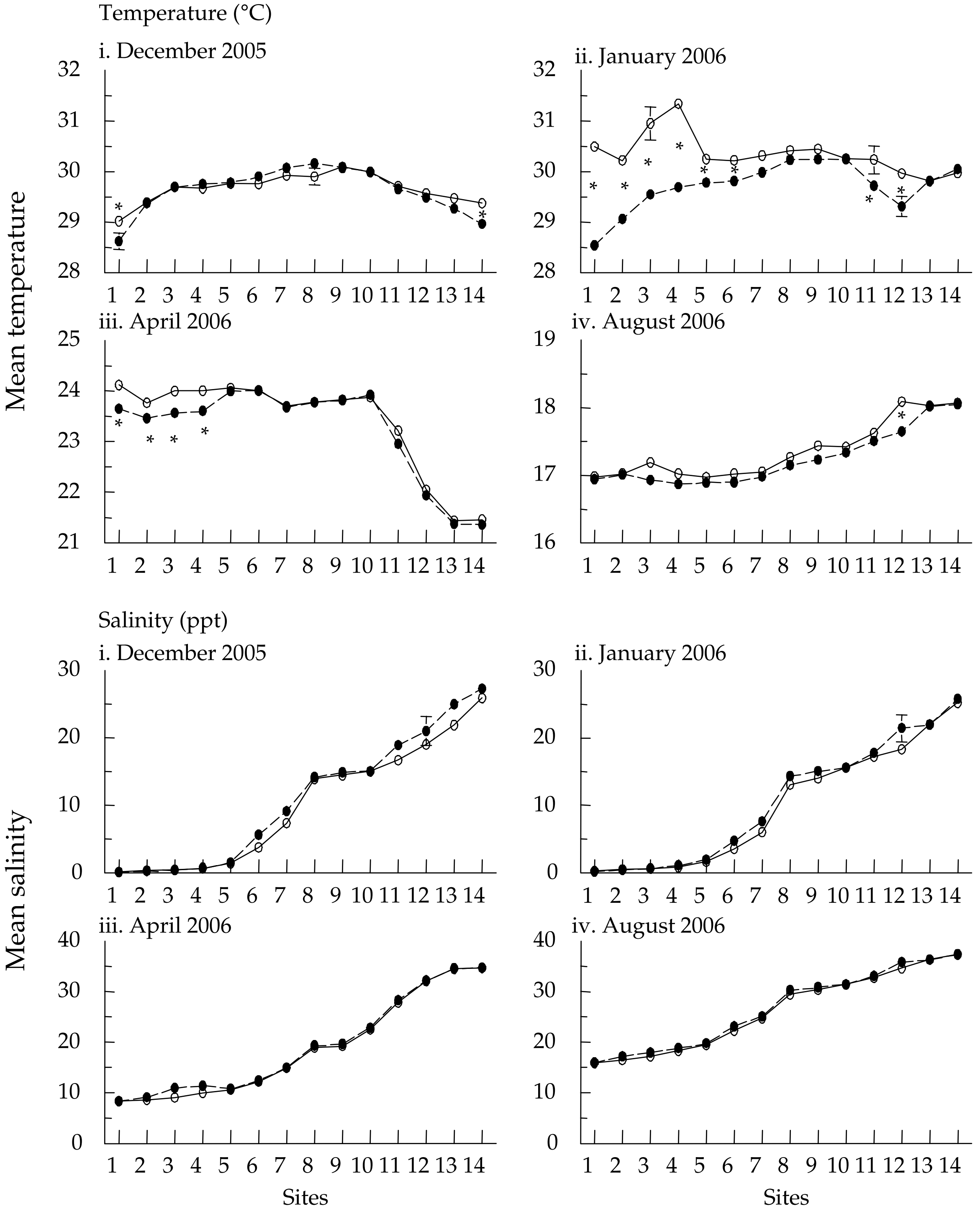


Figure 13a. Mean values (± 1 SE) of temperature and salinity measured in the Caboolture River (Dec. 2005 – Aug. 2006). Sites extend downstream from the weir (Site 1) to opposite the Beachmere boat ramp (Site 14). Sites 4 – 10 are adjacent to the NEBP project site. Open and closed circles = water surface and bottom, respectively (*n* = 2). Significant differences (SNK tests) between depth shown by asterisks.

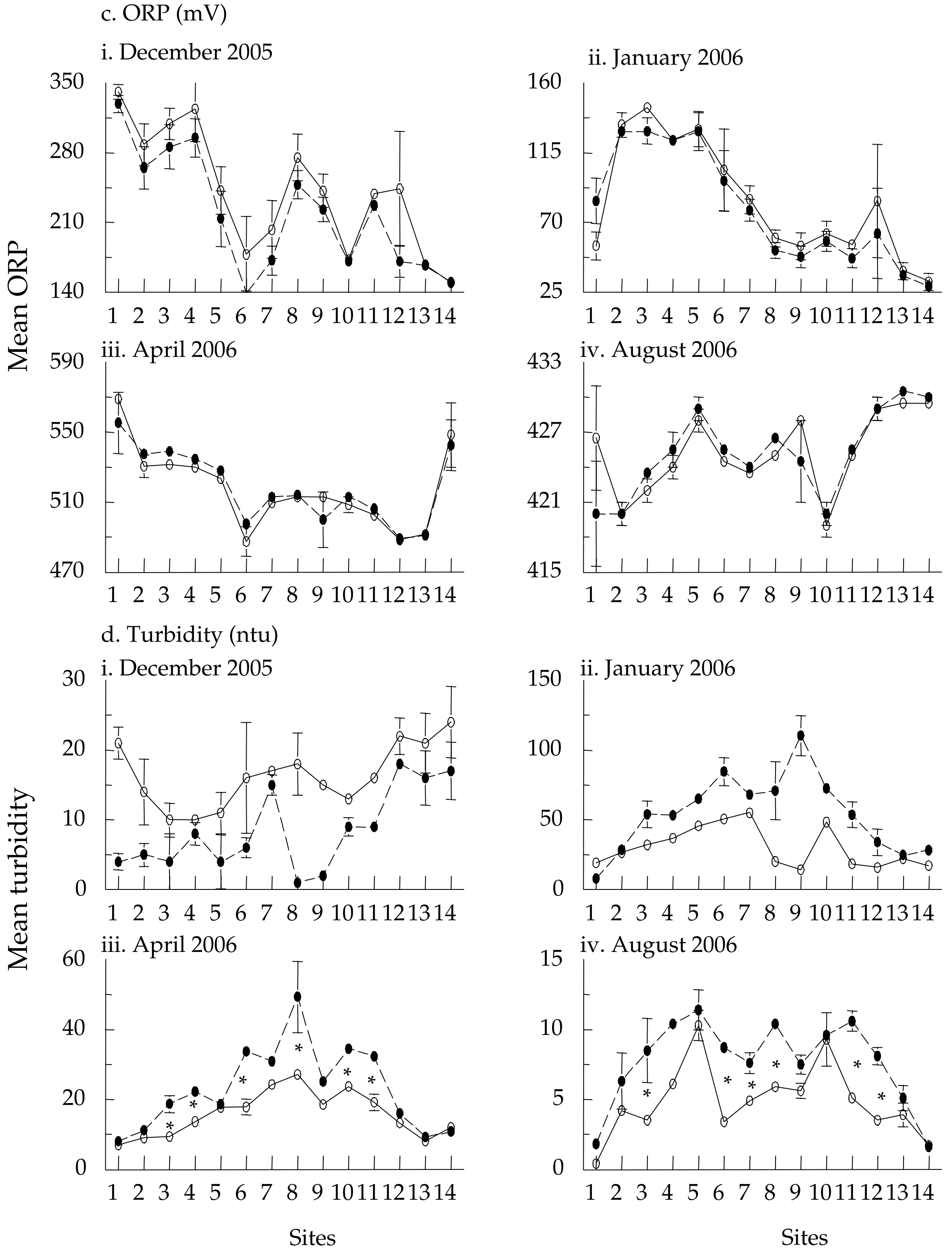


Figure 13b. Mean values (± 1 SE) of ORP and Turbidity measured in the Caboolture River (Dec. 2005 – Aug. 2006). Sites extend downstream from the weir (1) to opposite the Beachmere boat ramp (14). Sites 4 – 10 are adjacent to the NEBP project site. Open and closed circles = water surface and bottom, respectively (*n* = 2). Significant differences (SNK tests) between depth shown by asterisks.

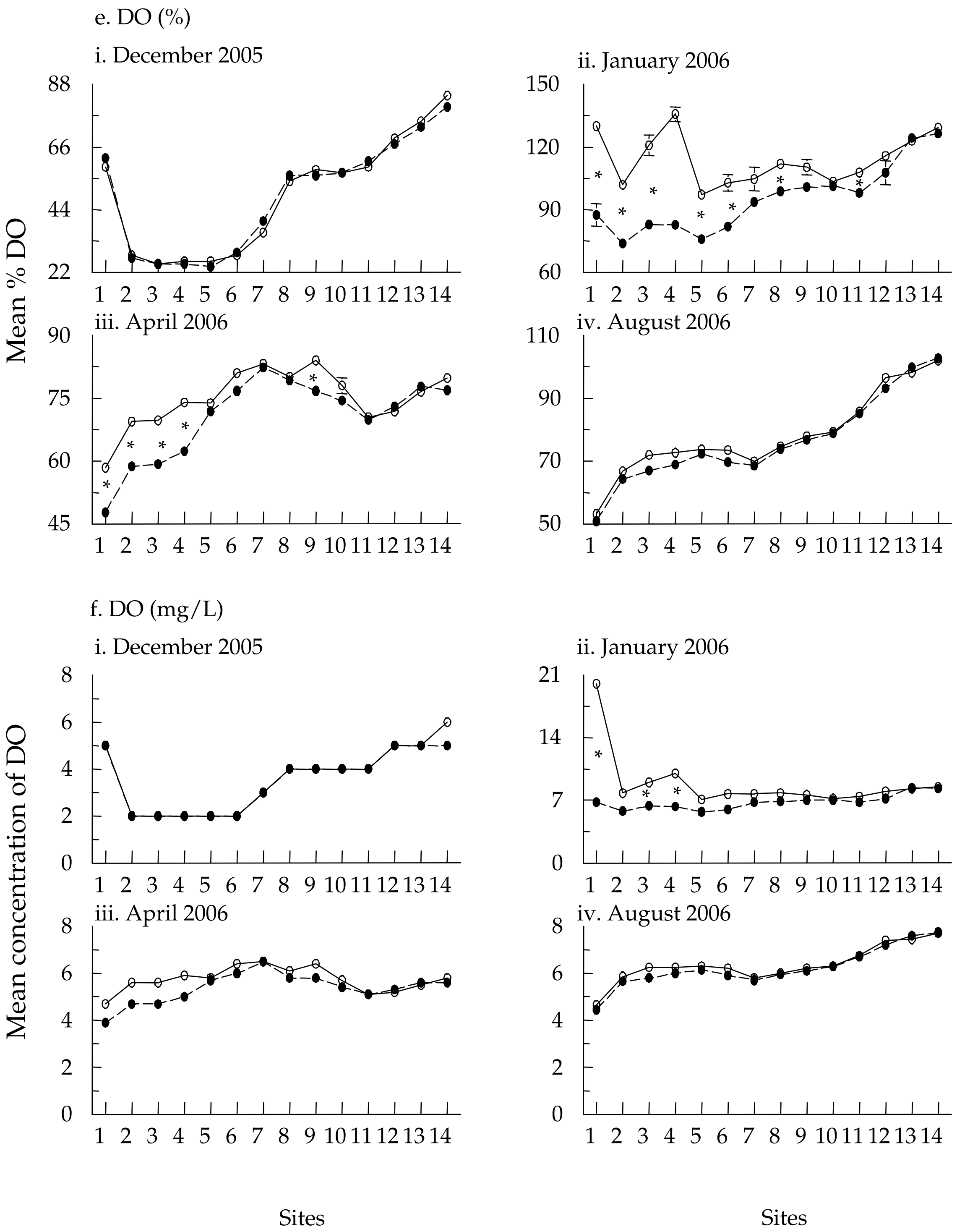


Figure 13c. Mean values (± 1 SE) of DO (%) and DO (mg/L) measured in the Caboolture River (Dec. 2005 – Aug. 2006). Sites extend downstream from the weir (1) to opposite the Beachmere boat ramp (14). Sites 4 – 10 are adjacent to the NEBP project site. Open and closed circles = water surface and bottom, respectively (*n* = 2). Significant differences (SNK tests) between depth shown by asterisks.

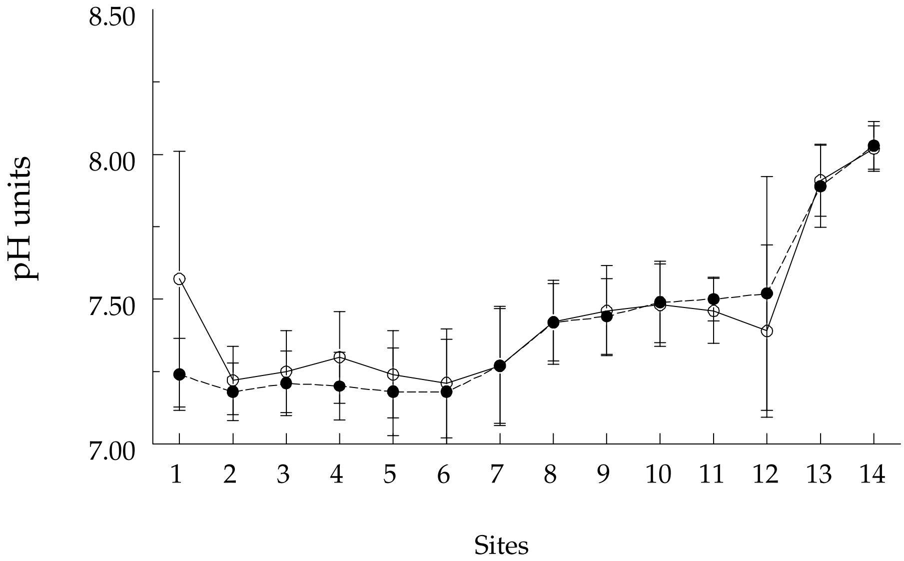


Figure 13d. Mean values (± 1 SE) of pH measured in the Caboolture River (Dec. 2005 – Aug. 2006 all times pooled). Sites extend downstream from the weir (1) to opposite the Beachmere boat ramp (14). Sites 4 – 10 are adjacent to the NEBP project site. Open and closed circles = water surface and bottom, respectively (*n* = 2).

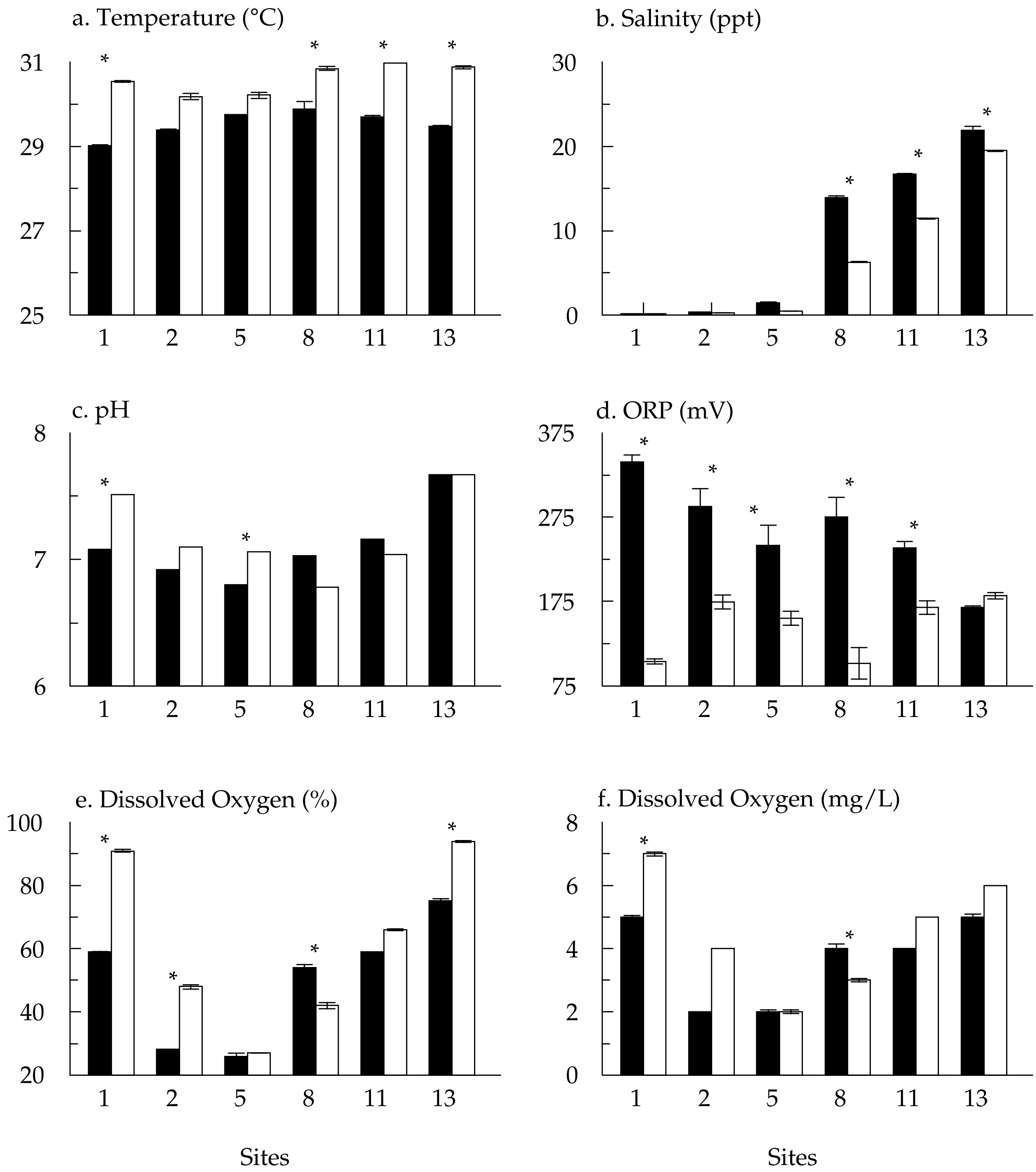


Figure 14. Mean values (± 1 SE) of surface water quality indicators measured in the Caboolture River (December 2005). Solid and open bars = morning and afternoon, respectively. Asterisks indicate significant differences (SNK tests) between times (n = 2).

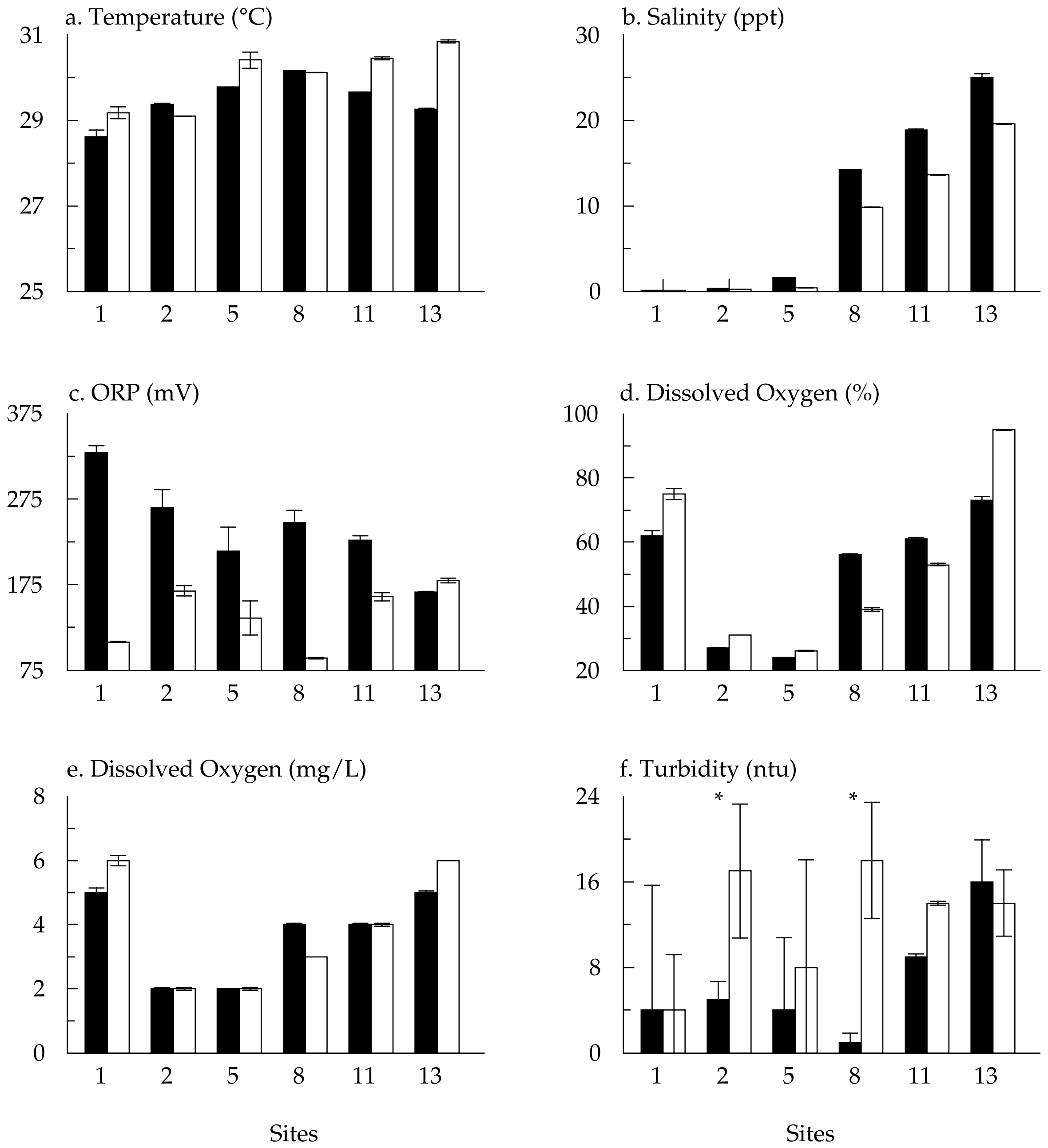


Figure 15. Mean values (± 1 SE) of bottom water quality indicators measured in the Caboolture River (December 2005). Solid and open bars = morning and afternoon, respectively. Asterisks indicate significant differences (SNK tests) between times ($n = 2$).

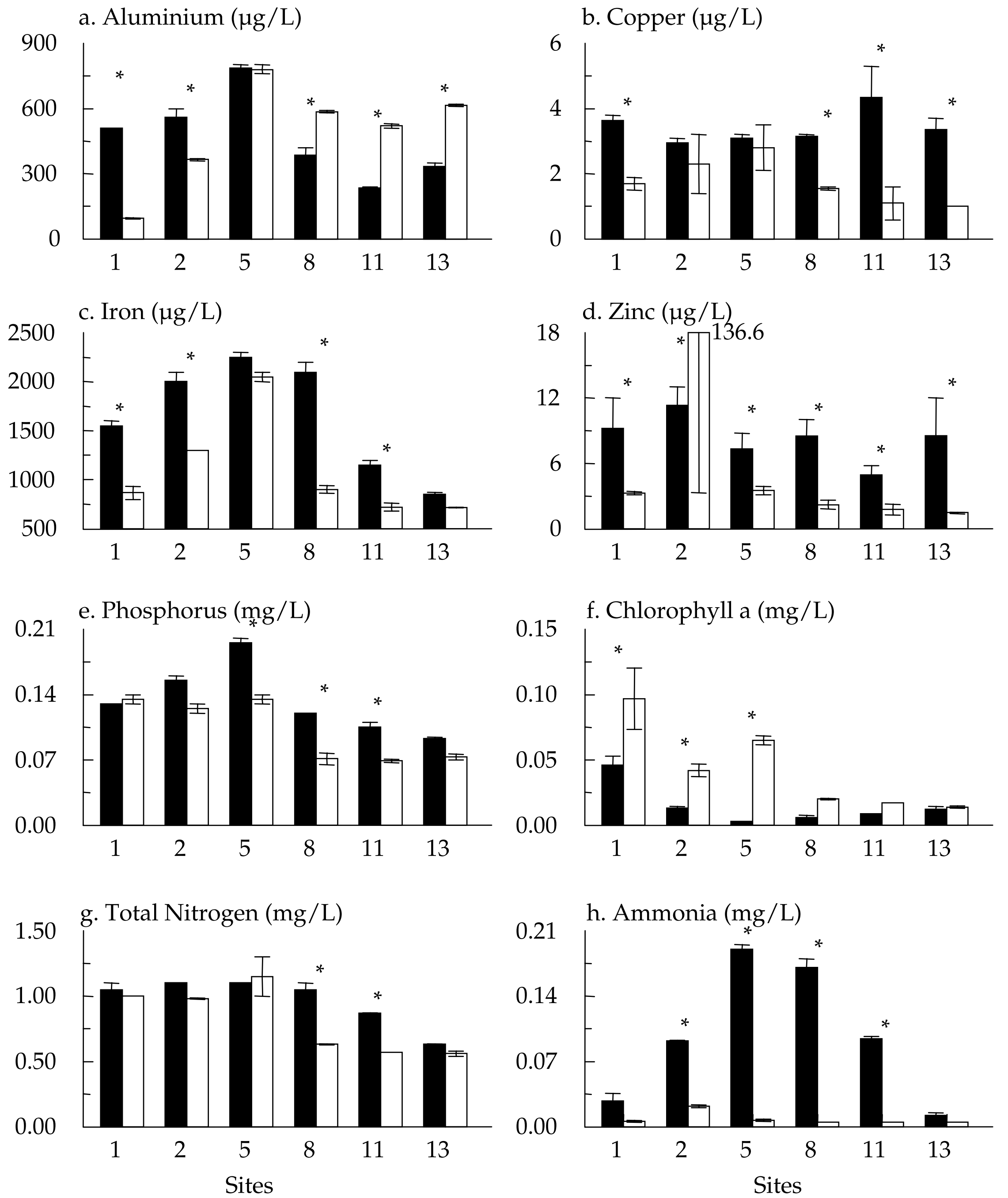


Figure 16. Mean values (± 1 SE) of surface water chemistry indicators measured in the Caboolture River. Solid and open bars = December 2005 and January 2006, respectively. Asterisks indicate significant differences between times ($n = 2$).

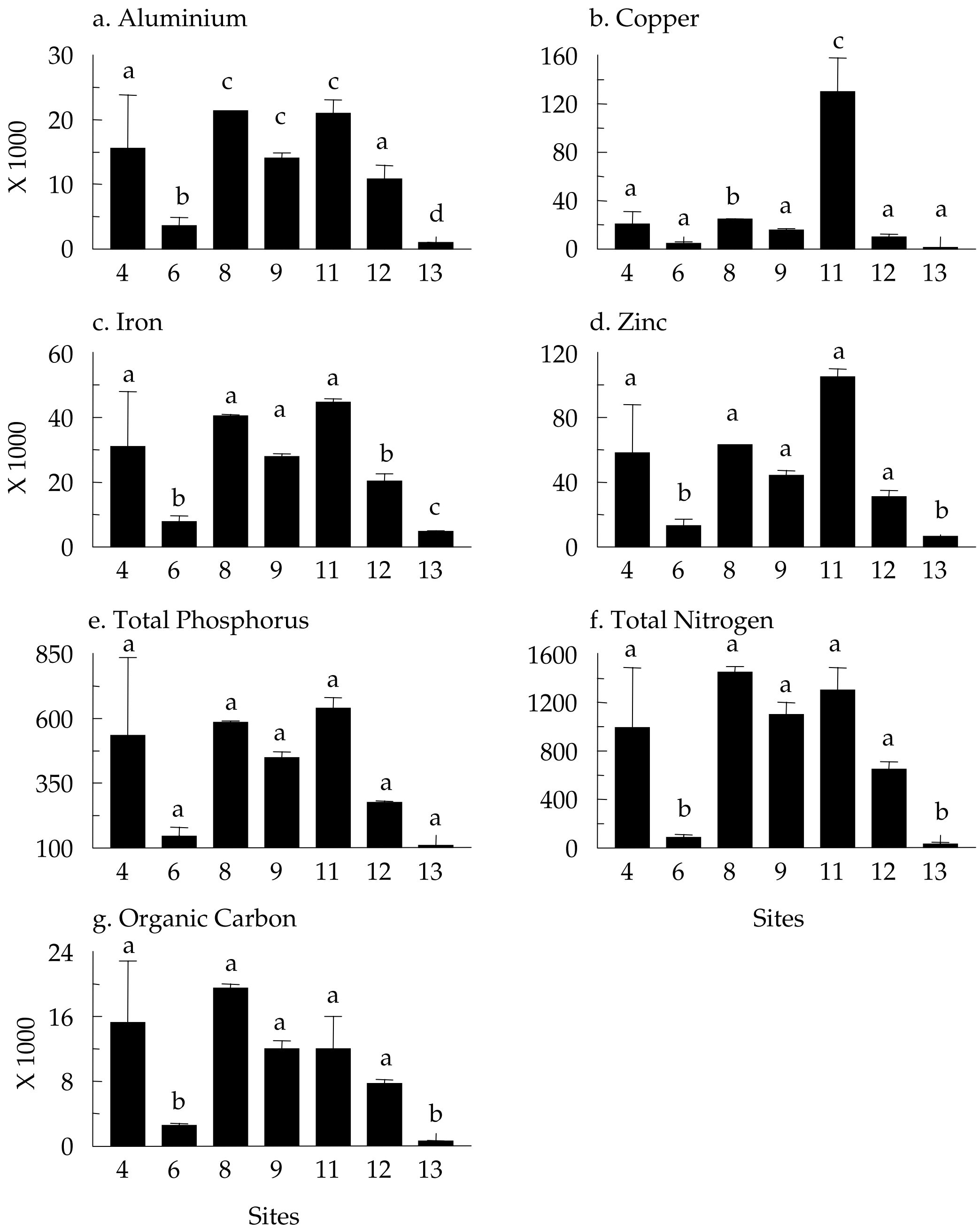
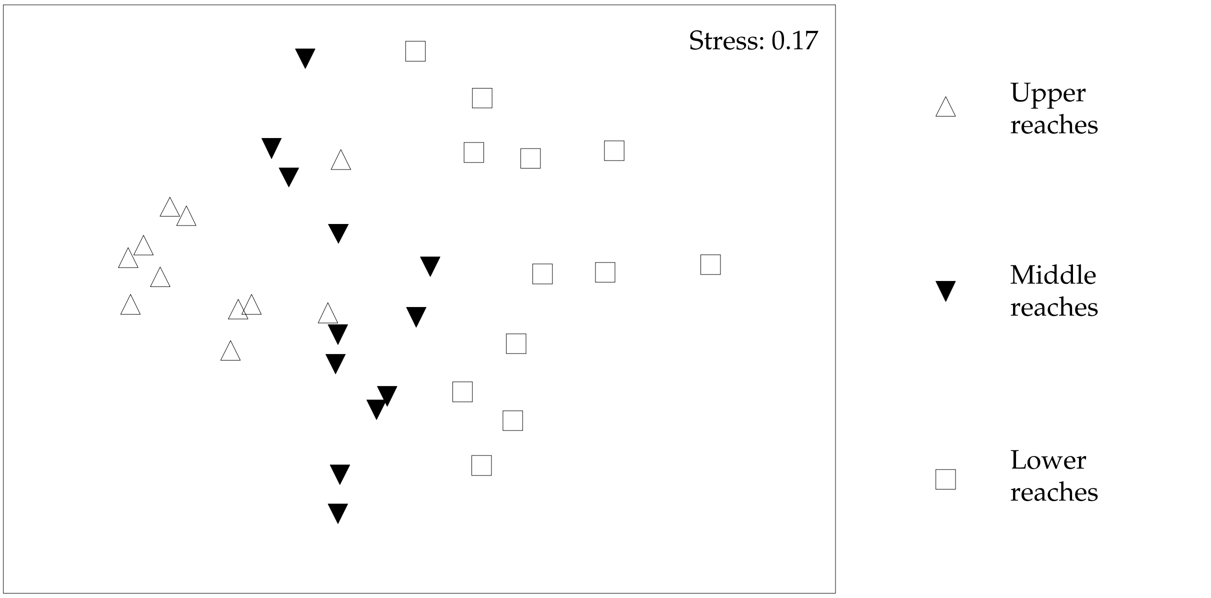
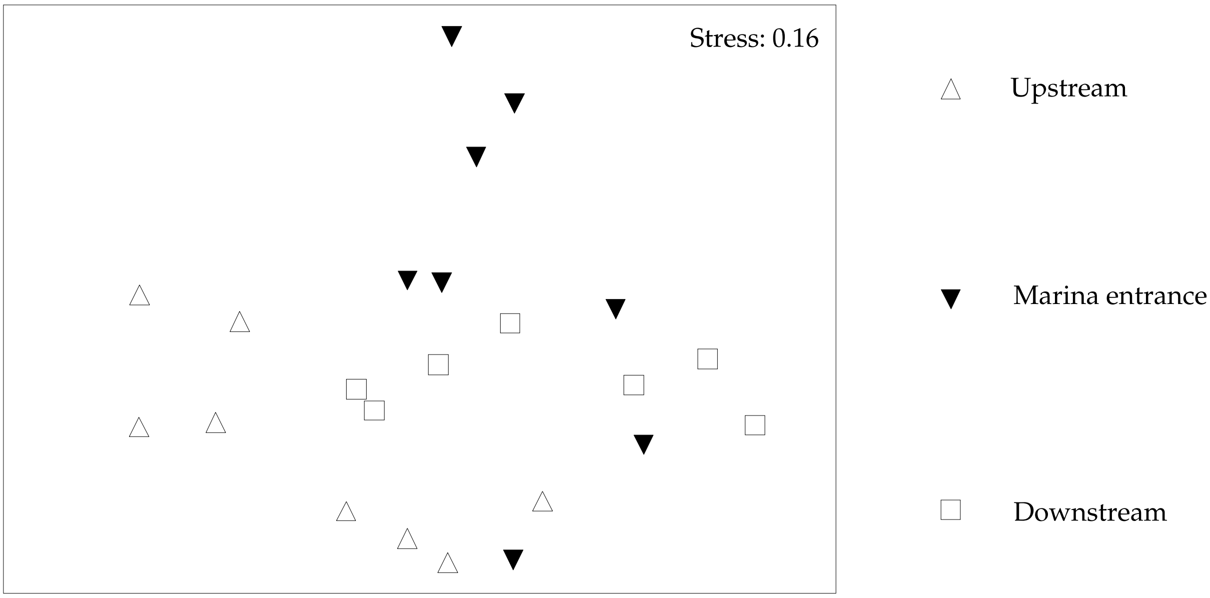


Figure 17. Mean values (± 1 SE) of sediment quality indicators (all mg/kg) measured in the Caboolture River (April 2006). Sites 4 – 9 are adjacent to the proposed the NEBP project site and sites 11 – 13 extend downstream to opposite the Beachmere boat ramp. Sites with different letters are significantly different. (*n* = 2).



a.



b.

Figure 18. nMDS of benthic assemblages in (a) channel (subtidal habitat) and (b) river bank (littoral habitat) localities along the Caboolture River.

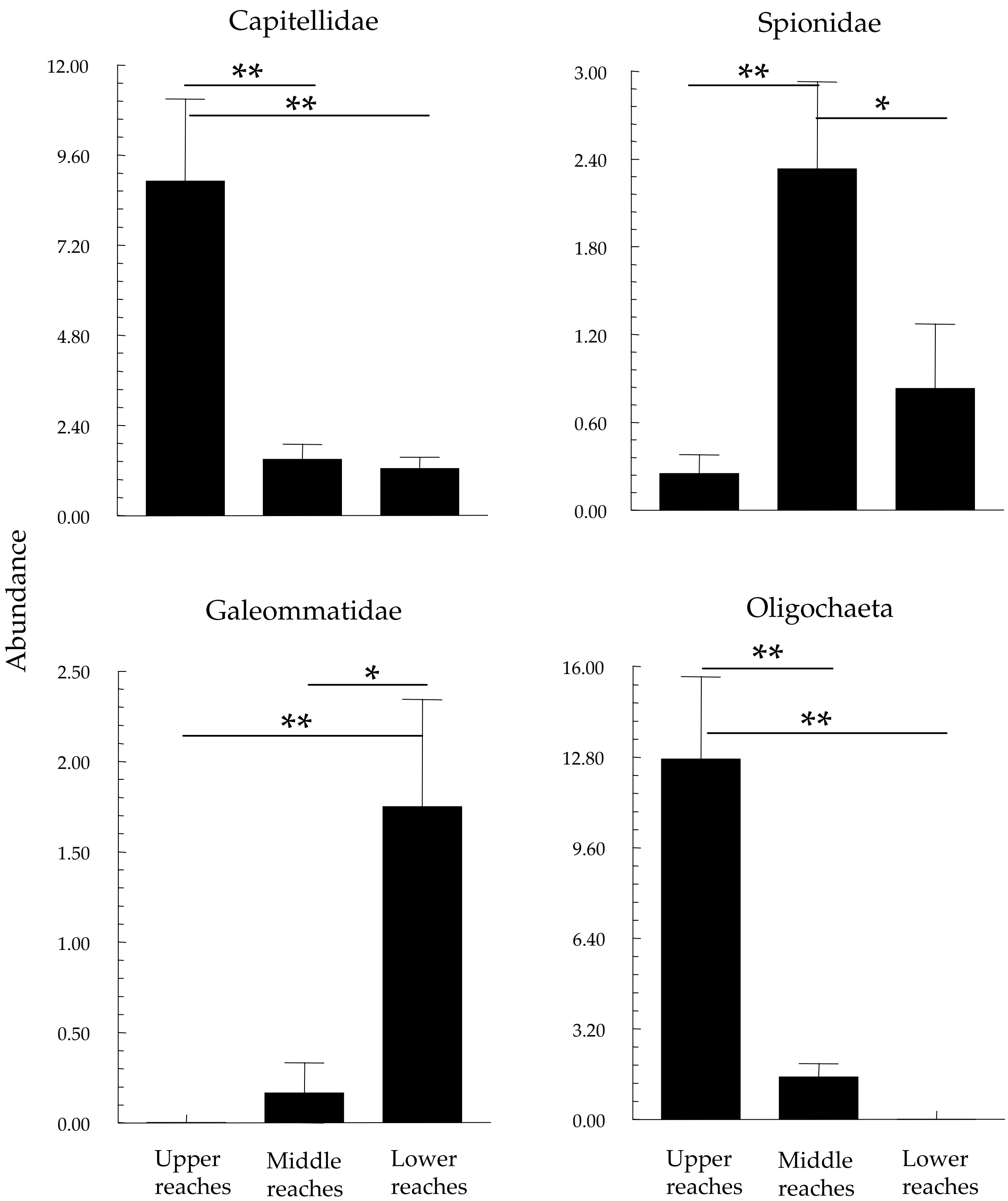


Figure 19. Taxa exhibiting significant differences among channel locations. Lines and asterisks indicate significance differences between locations (SNK tests: * $p < 0.05$; ** $p < 0.01$, $n = 12$).

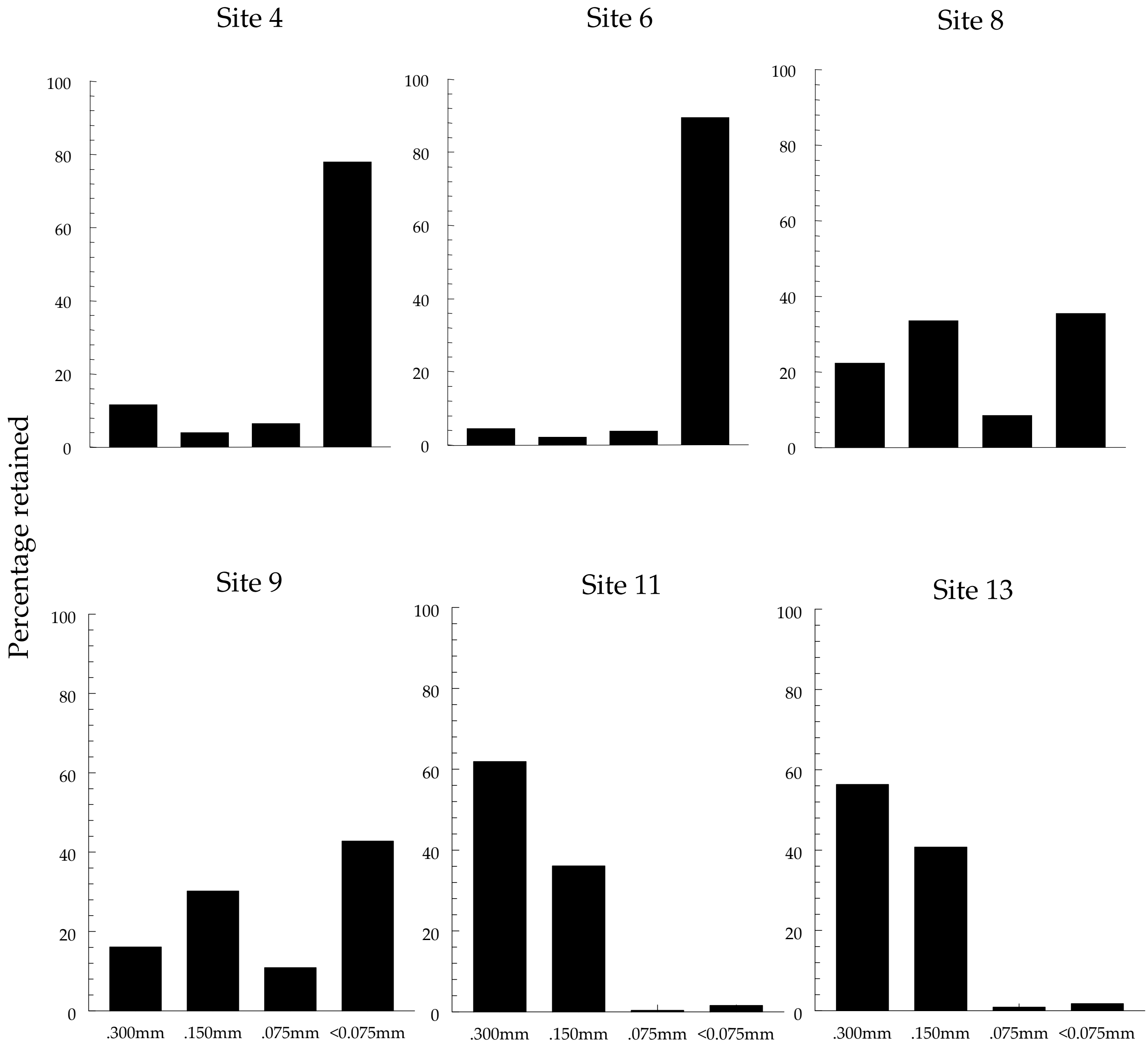


Figure 20. Sediment particle size distribution for selected sites at Caboolture.

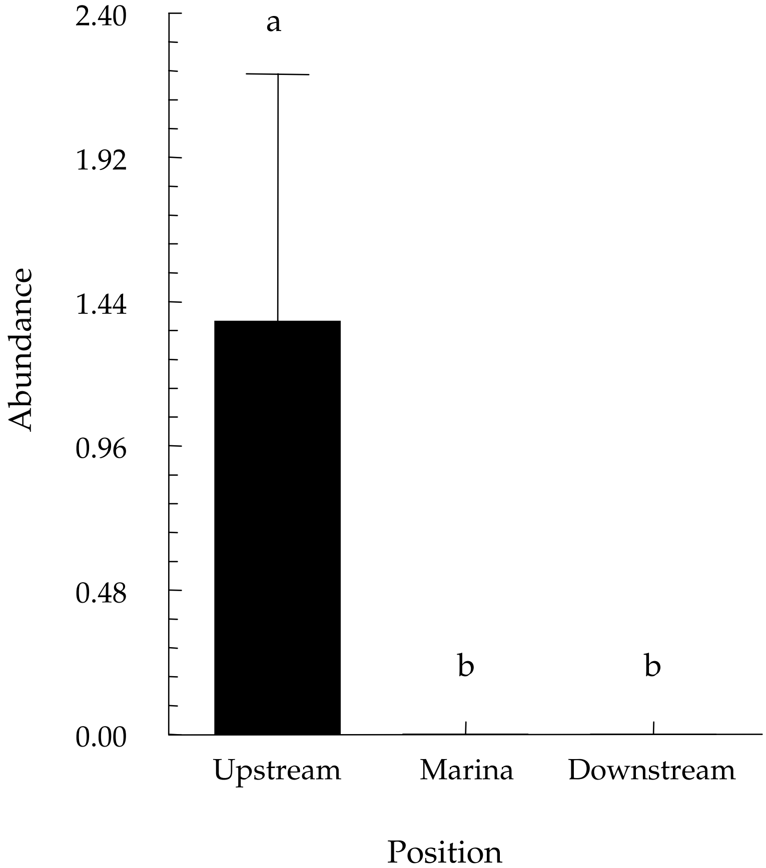


Figure 21. Mean abundance (± 1 SE) of Galeommatidae sampled in the bank habitat. Bars with the different letters not significantly different (SNK test, $P \leq 0.05$; $n = 12$).

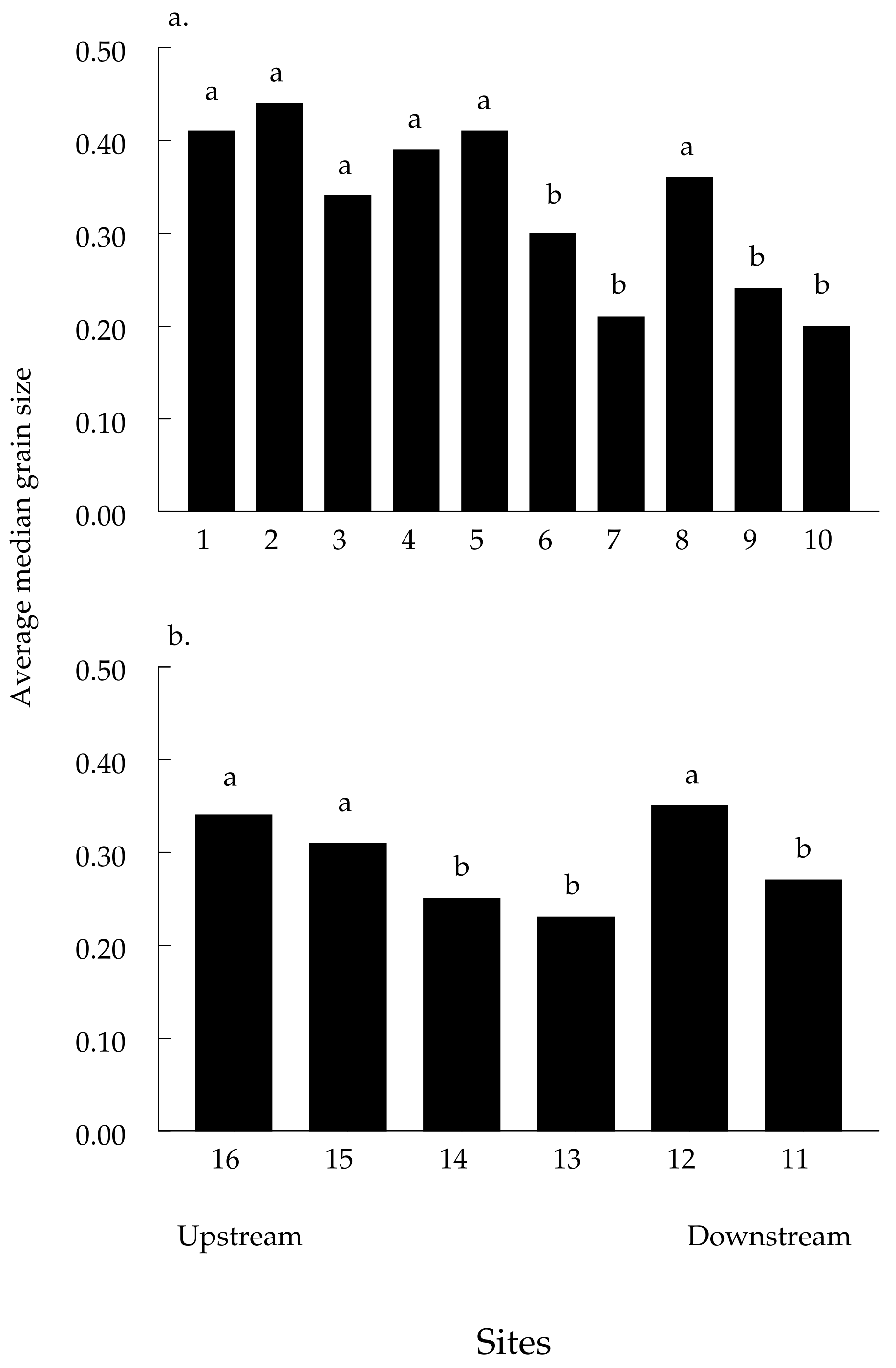


Figure 22. Average median grain size of sediments (mm) in (a) Channel and (b) Flats sites in and adjacent to the navigational channel, Caboolture River ($n = 2$) in March 2007. Standard errors were too small to be visible. Sites with different letters were significantly different (SNK tests; $p < 0.05$).

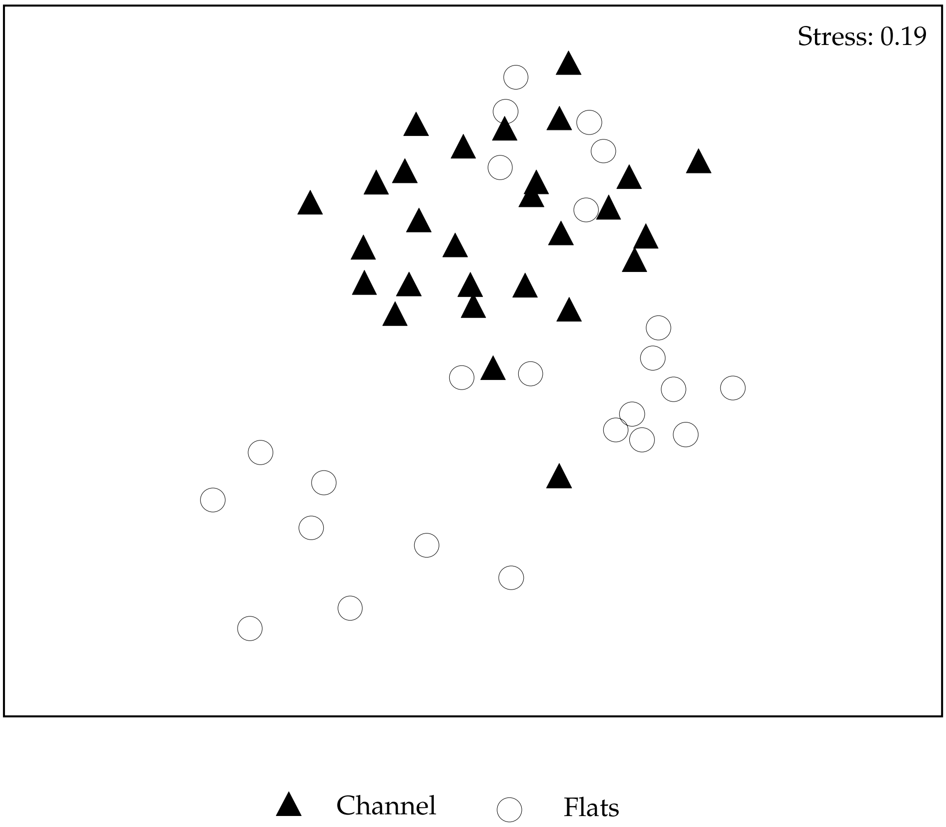


Figure 23. nMDS plot of macrobenthic assemblages in Channel and Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007.

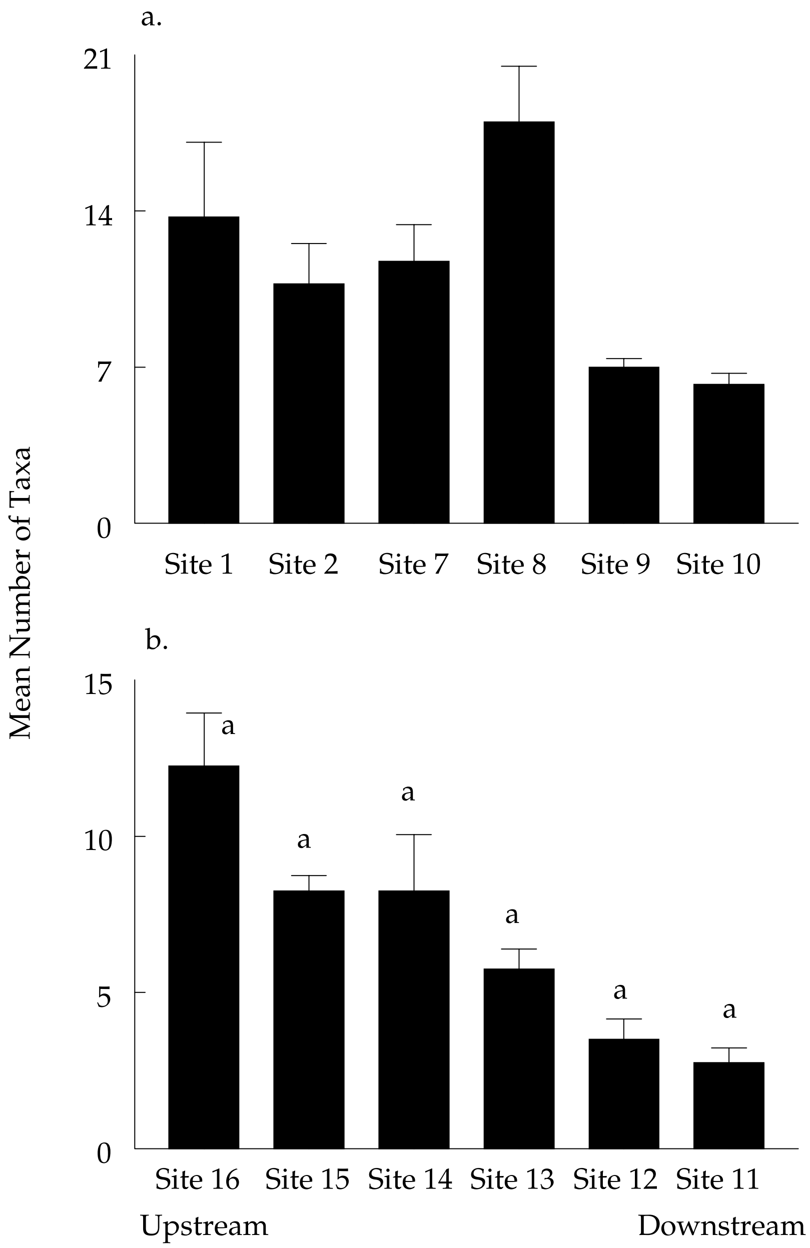


Figure 24. Mean total number of taxa (± SE) at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (SNK tests; p < 0.05).

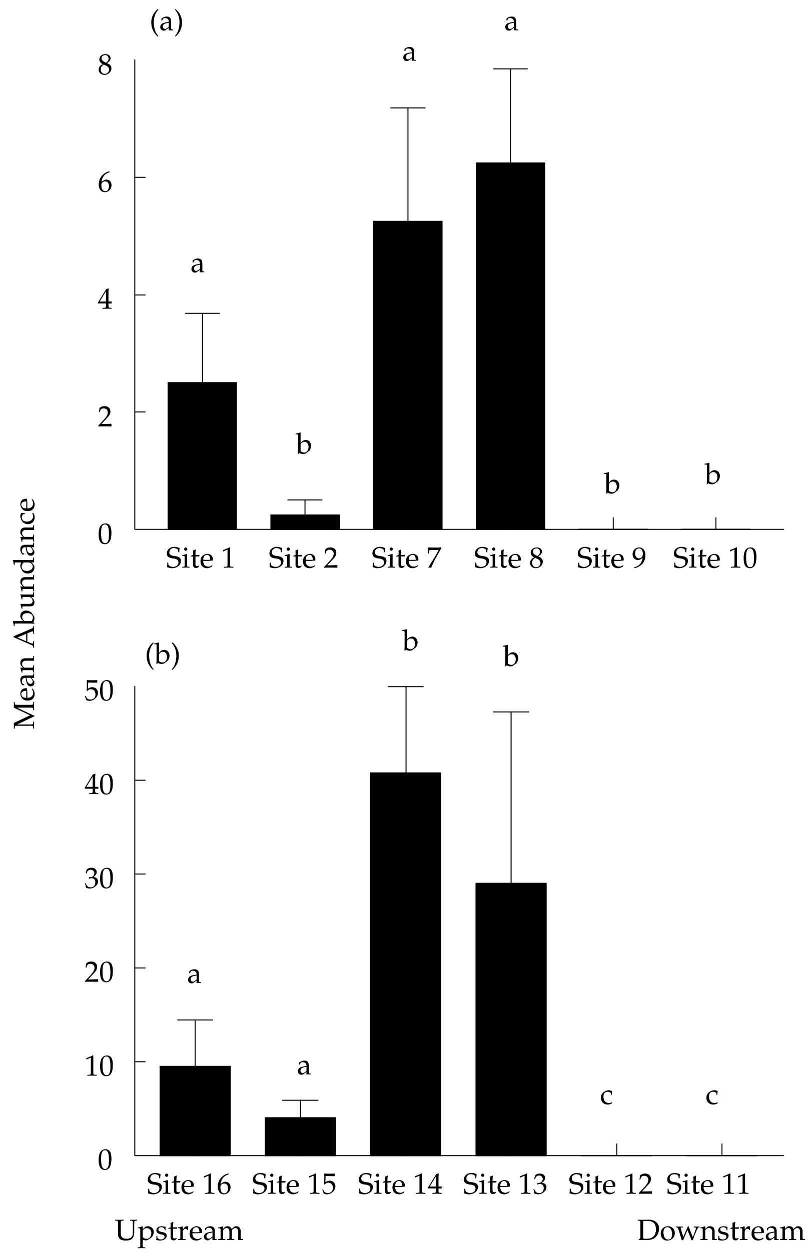


Figure 25. Mean abundance (± SE) of Oweniidae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 ($n = 4$). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

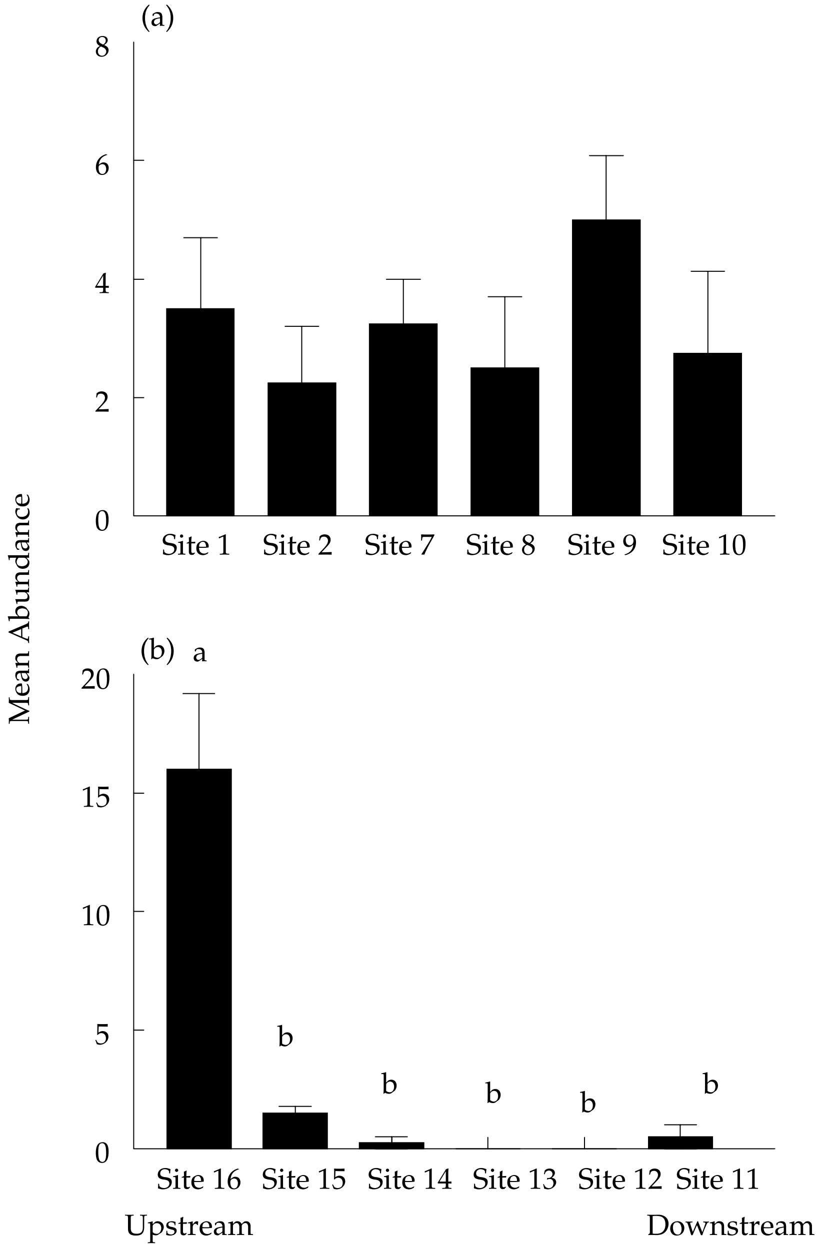


Figure 26. Mean abundance (± SE) of Capitellidae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

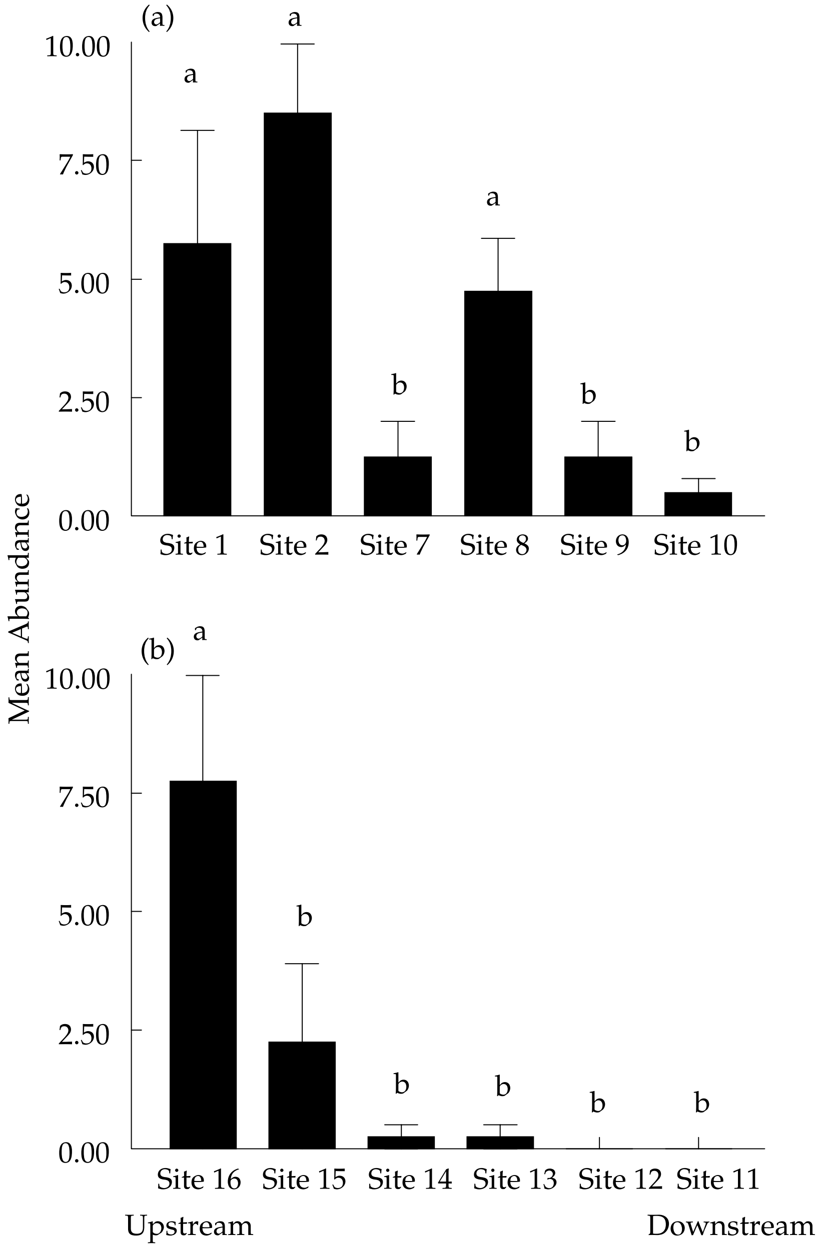


Figure 27. Mean abundance (± SE) of Lucinidae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

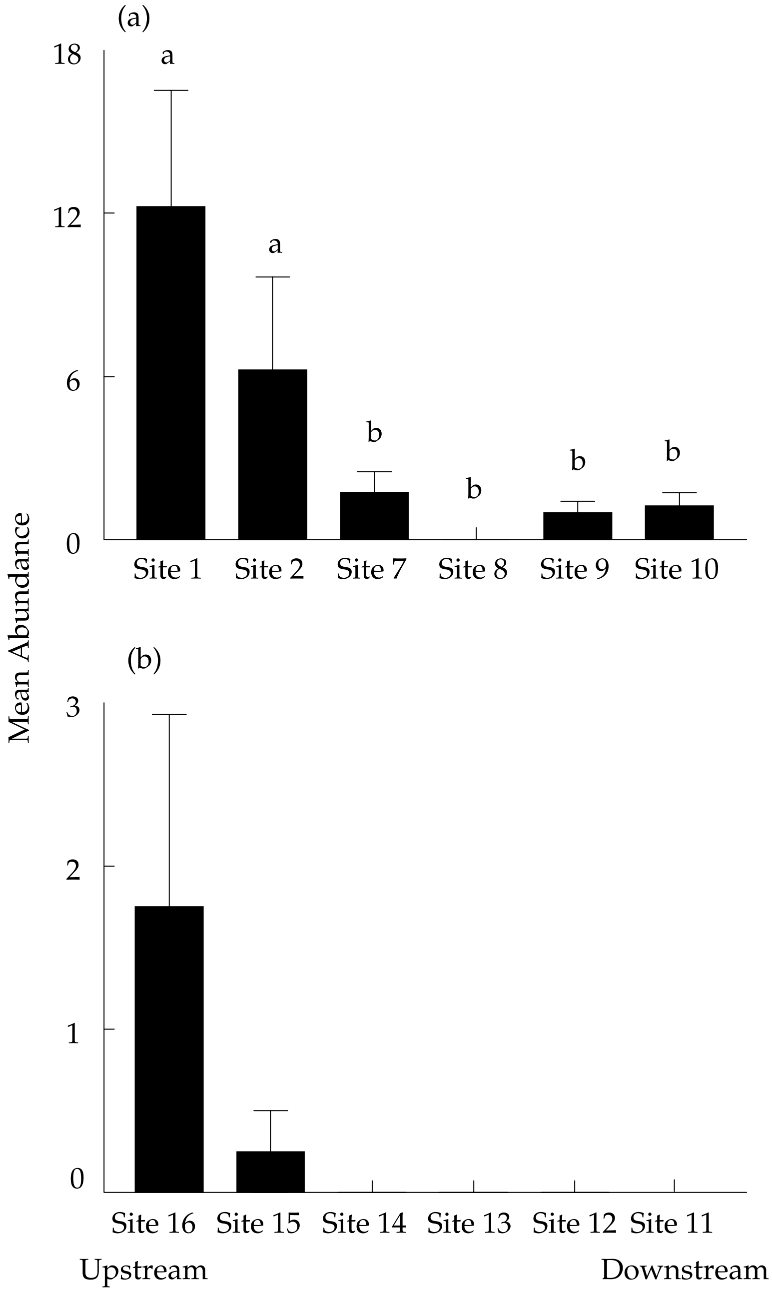


Figure 28. Mean abundance (± SE) of Lumbrineridae at sites in (A) Channel and (B) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 ($n = 4$). Sites with different letters were significantly different (SNK Tests; $p < 0.05$).

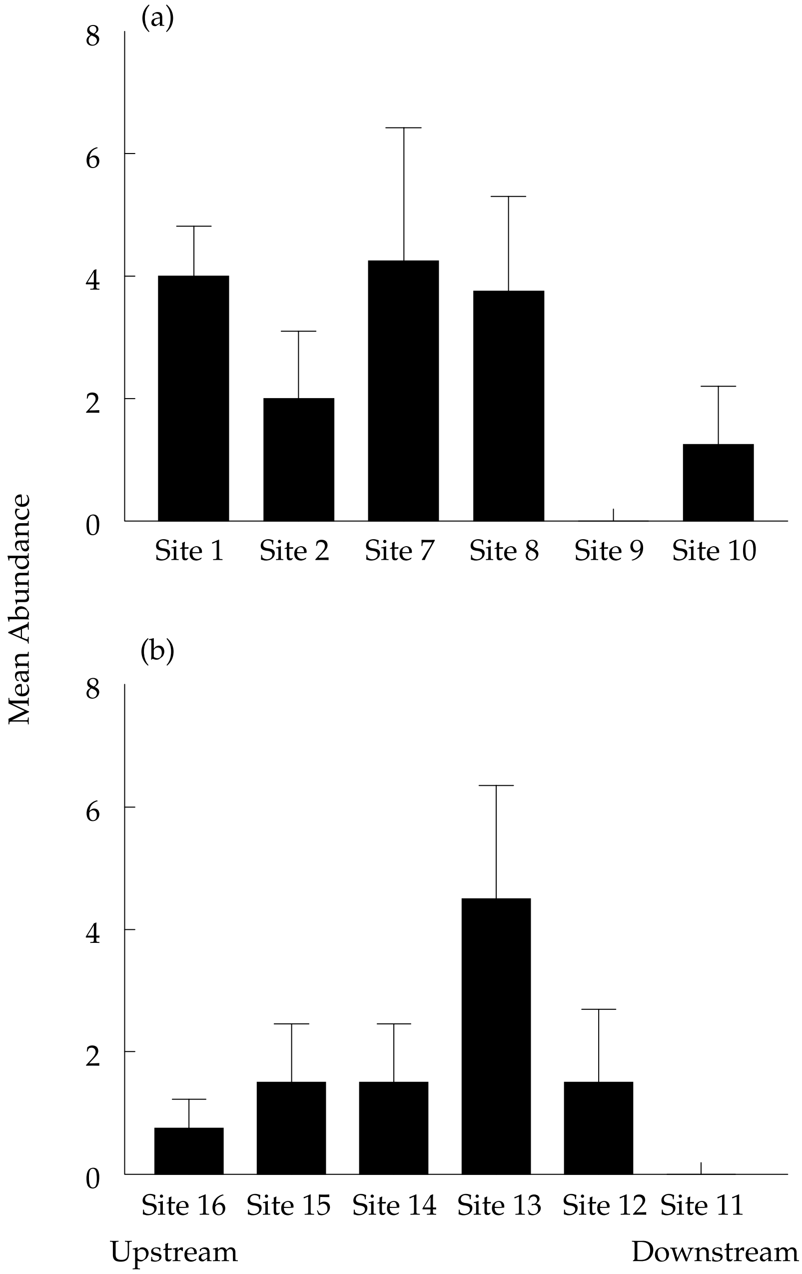


Figure 29. Mean abundance (± SE) of Galeommatidae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

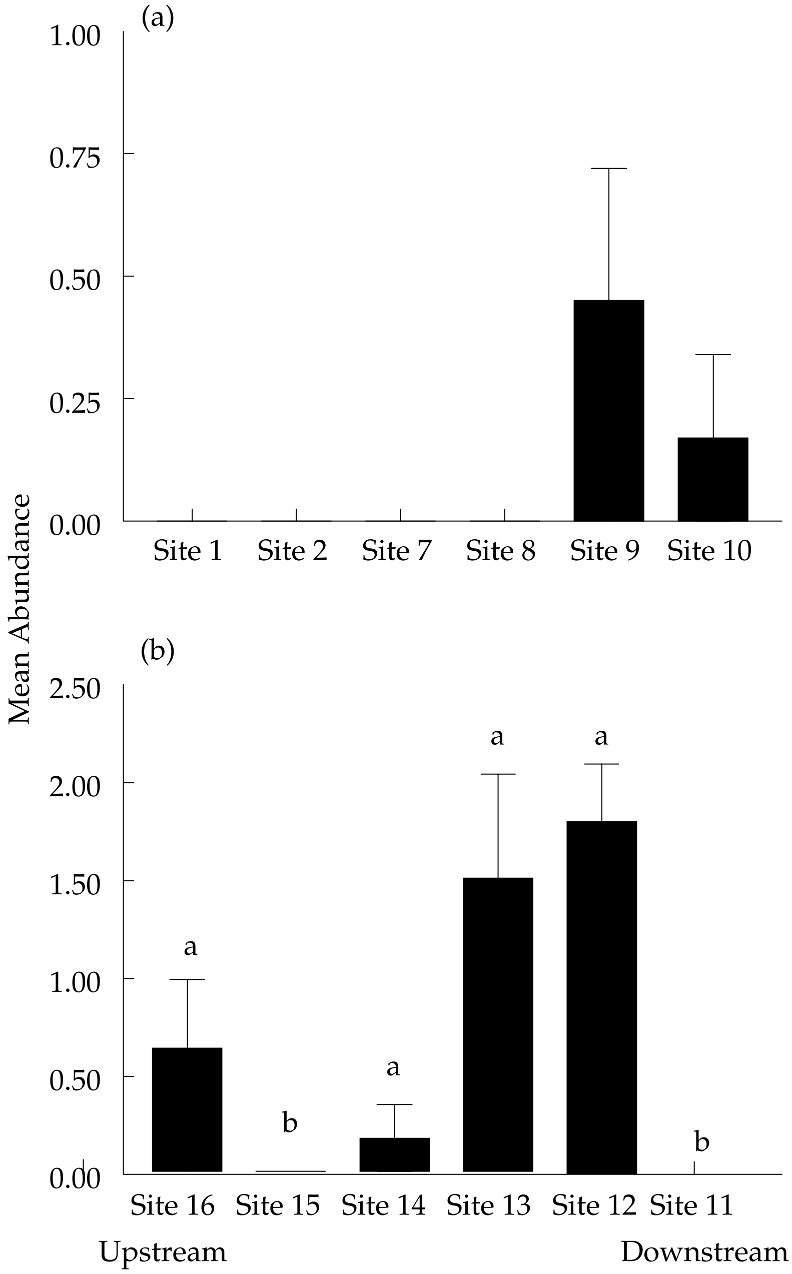


Figure 30. Mean abundance (± SE) of Orbiniidae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (SNK tests; p < 0.05).

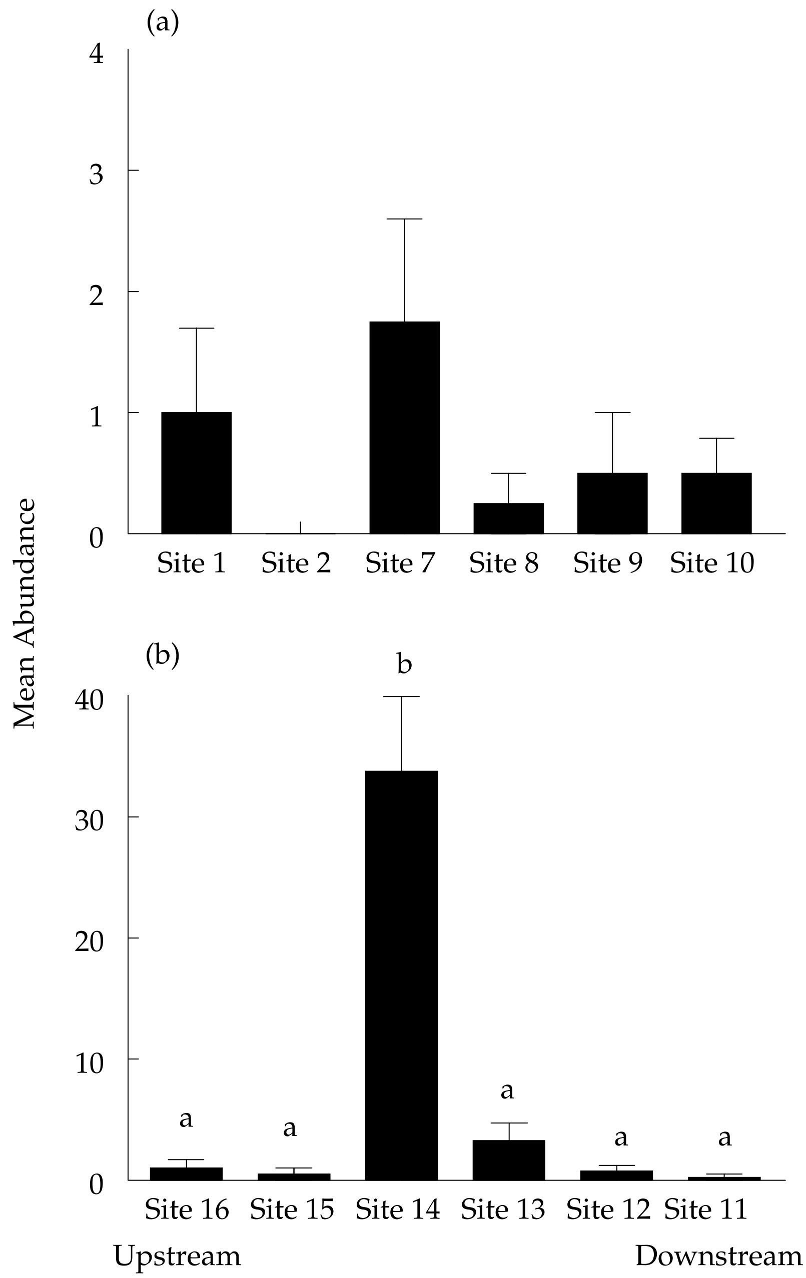


Figure 31. Mean abundance (± SE) of Glyceridae at sites in (a) Channel and (b) Flats localities in and adjacent to the navigational channel, Caboolture River in March 2007 (n = 4). Sites with different letters were significantly different (p < 0.05).

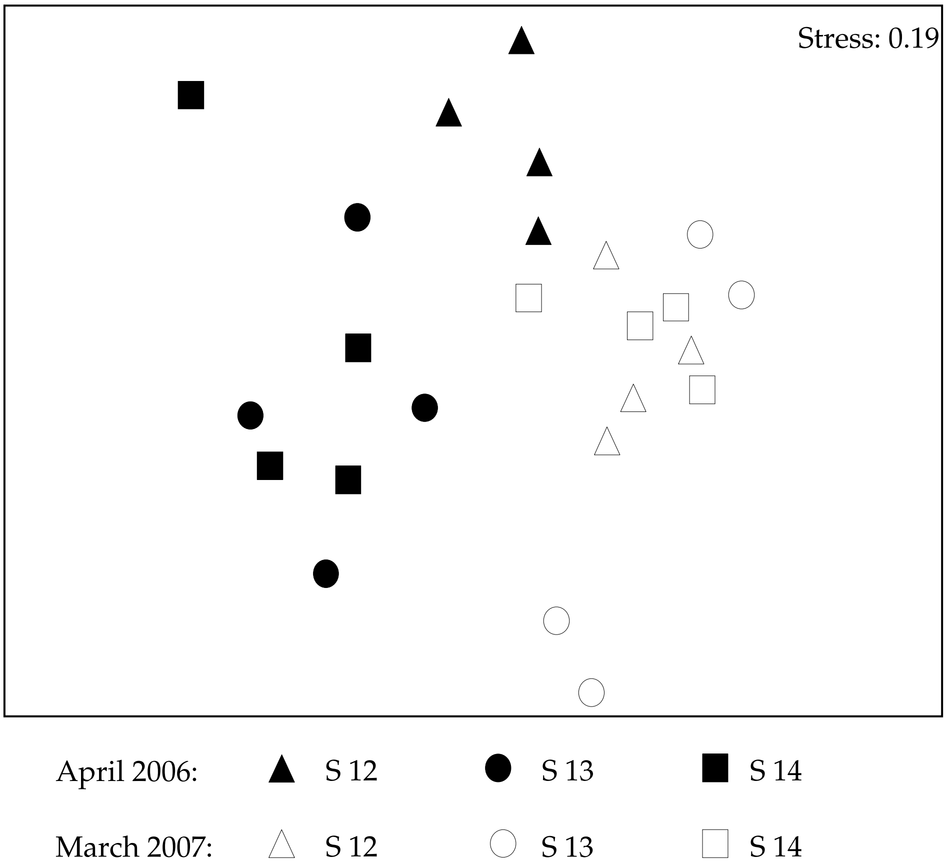


Figure 32. nMDS of macrobenthic assemblages in Channel sites 12, 13 and 14 in April 2006 and March 2007 in the navigational channel, Caboolture River.

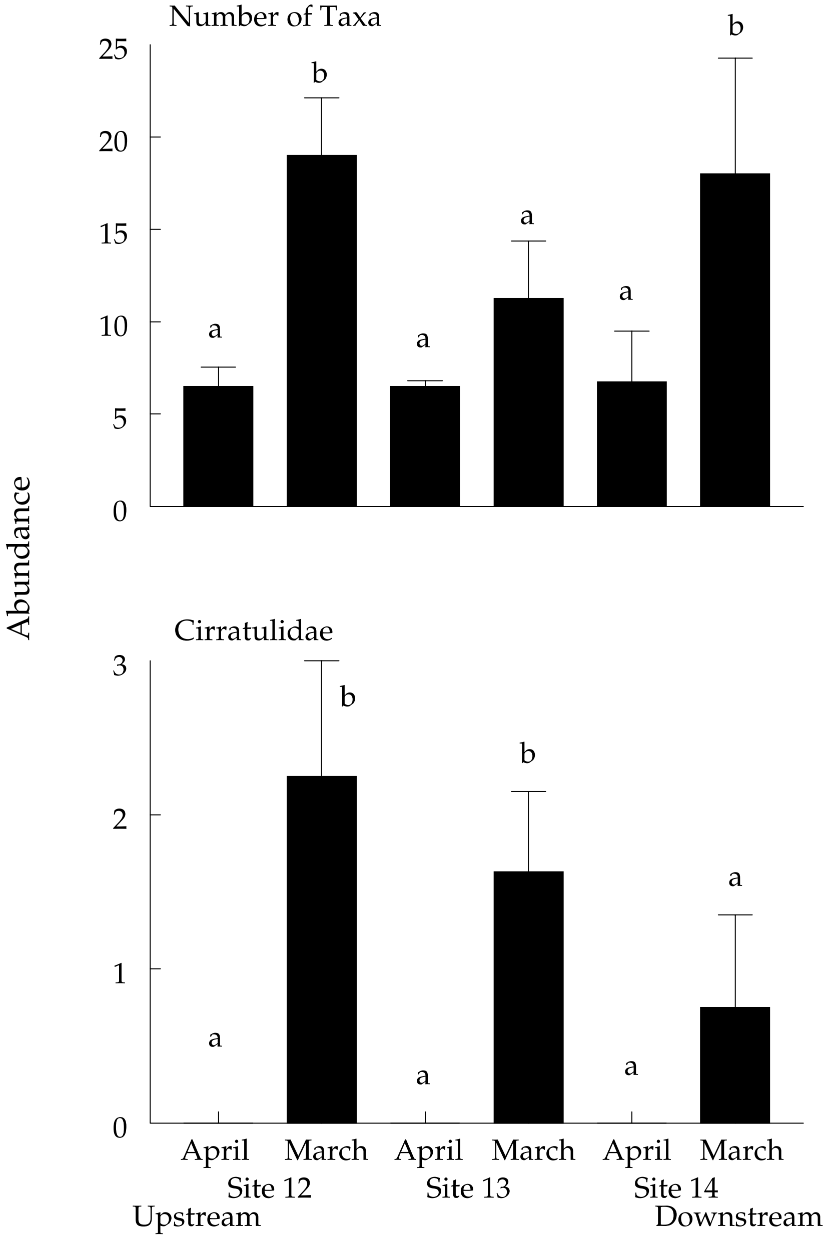


Figure 33. Mean total number of taxa (± SE) and abundance of Cirratulidae at Channel sites in April 2006 and March 2007 in the navigational channel, Caboolture River (n = 4). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

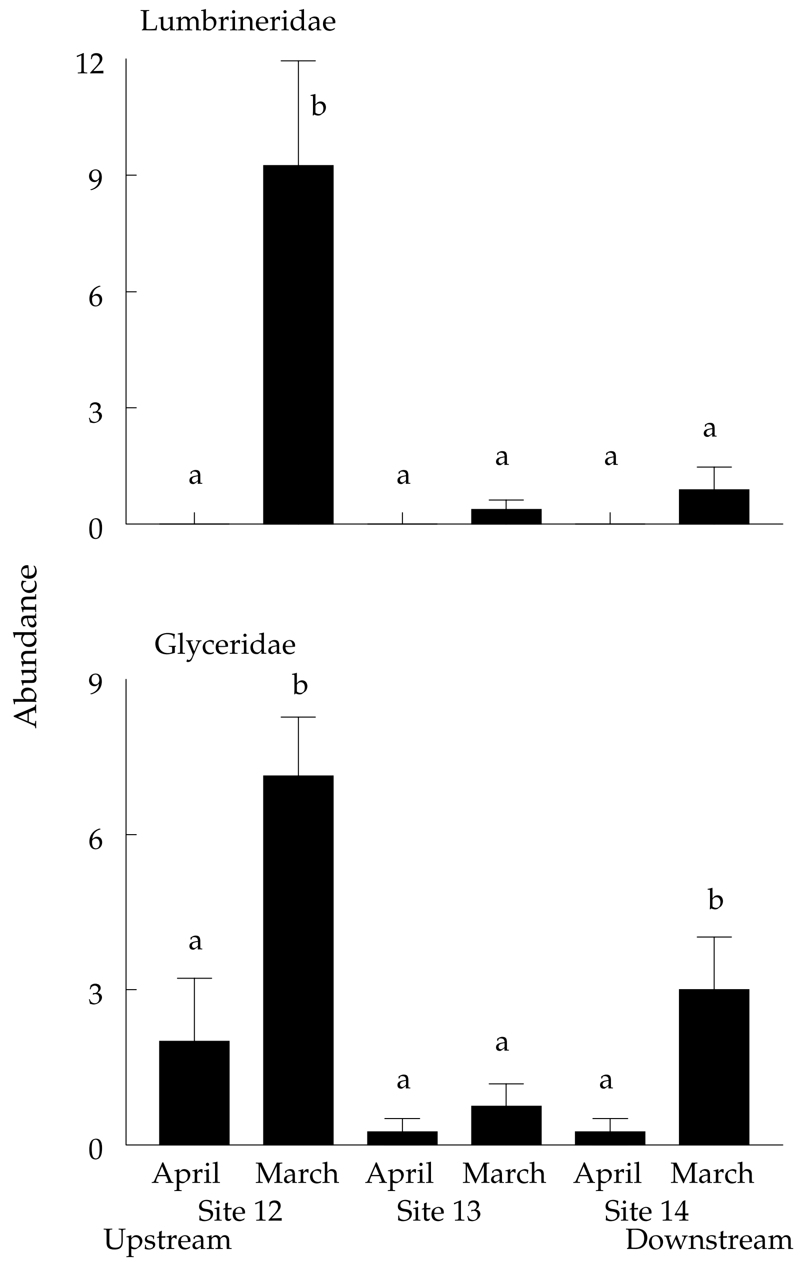


Figure 34. Mean abundance (± SE) of Lumbrineridae and Glyceridae at Channel sites in April 2006 and March 2007 in the navigational channel, Caboolture River (*n* = 4). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

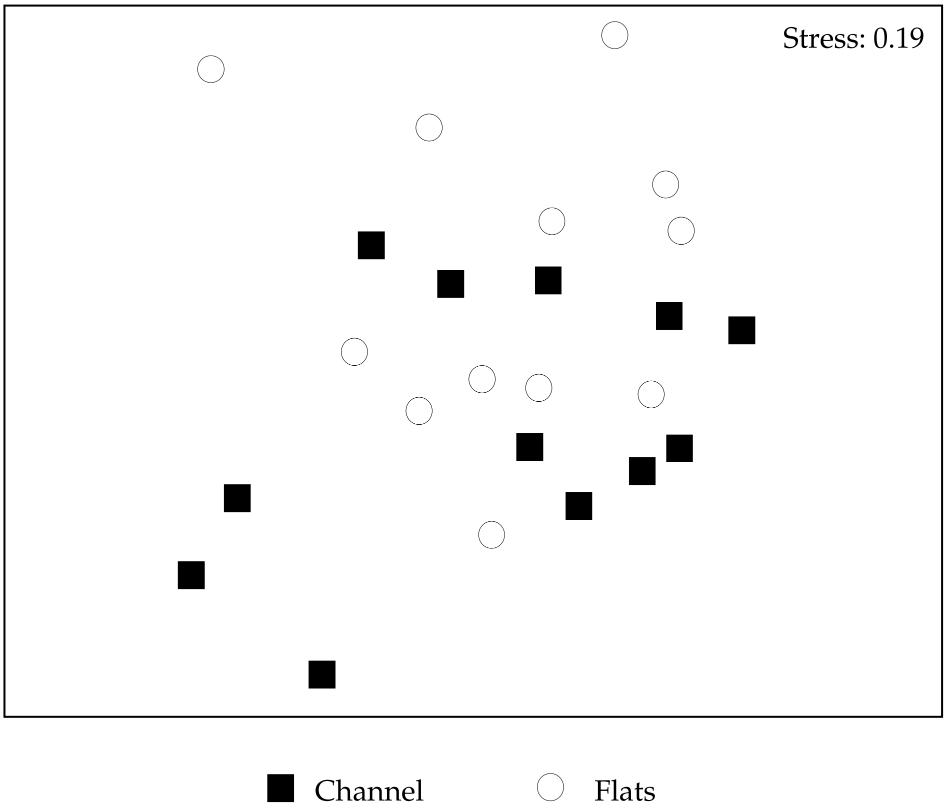


Figure 35. nMDS of fish assemblages at Channel and Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007.

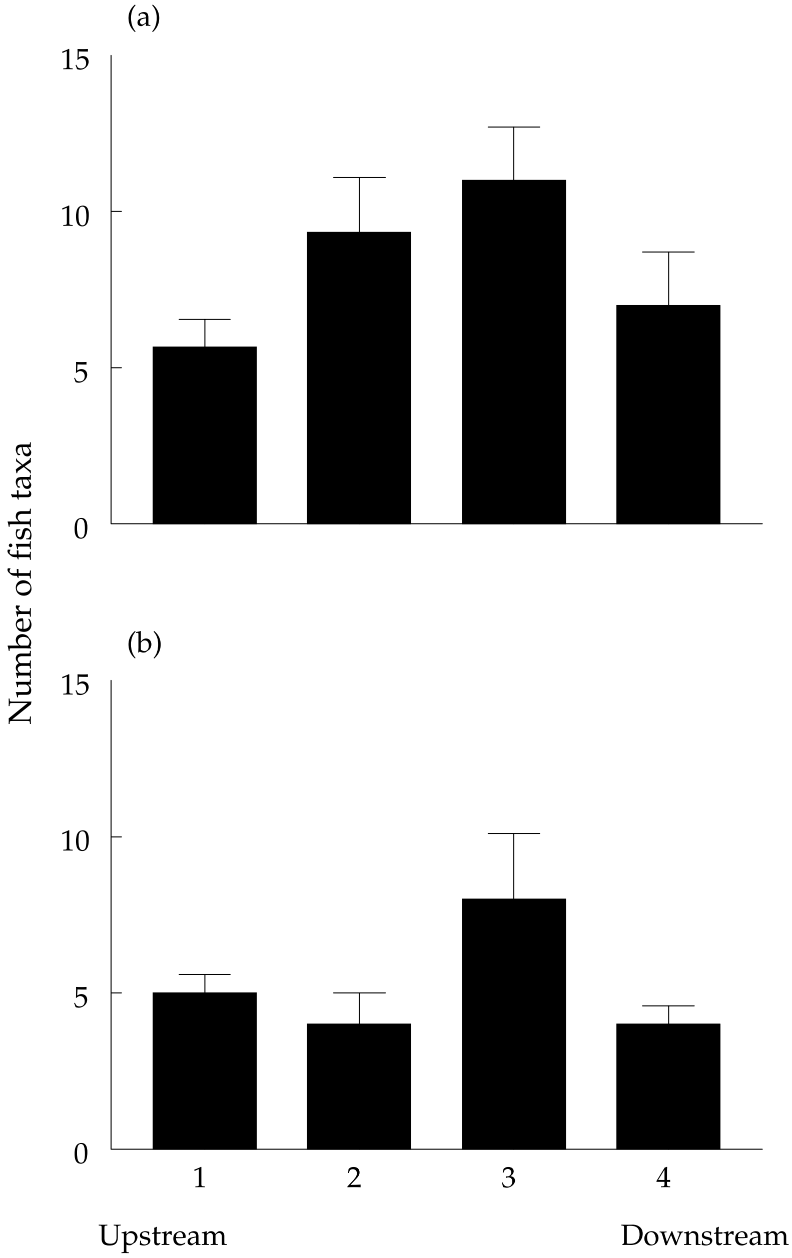


Figure 36. Mean total number of fish taxa (± SE) at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in Caboolture (n = 3) in March 2007.

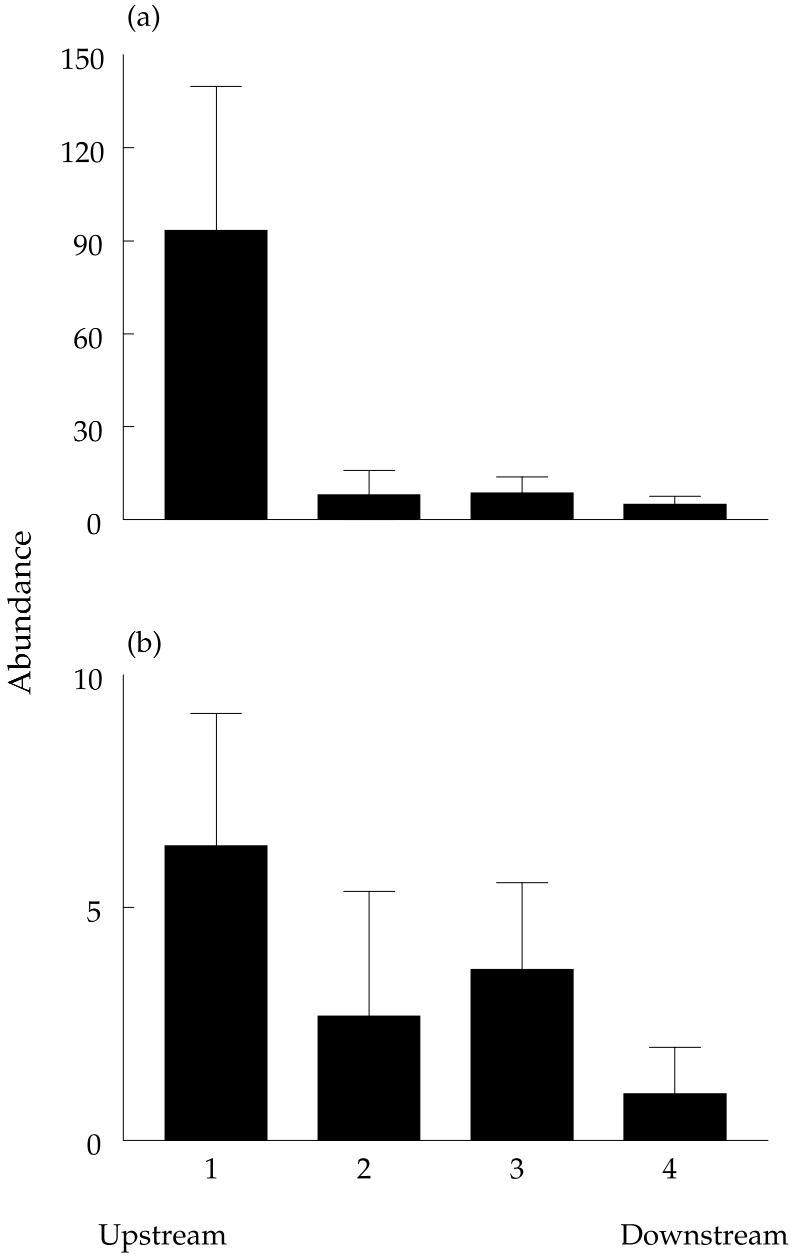


Figure 37. Mean abundance (± SE) of *Engraulis australis* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3).

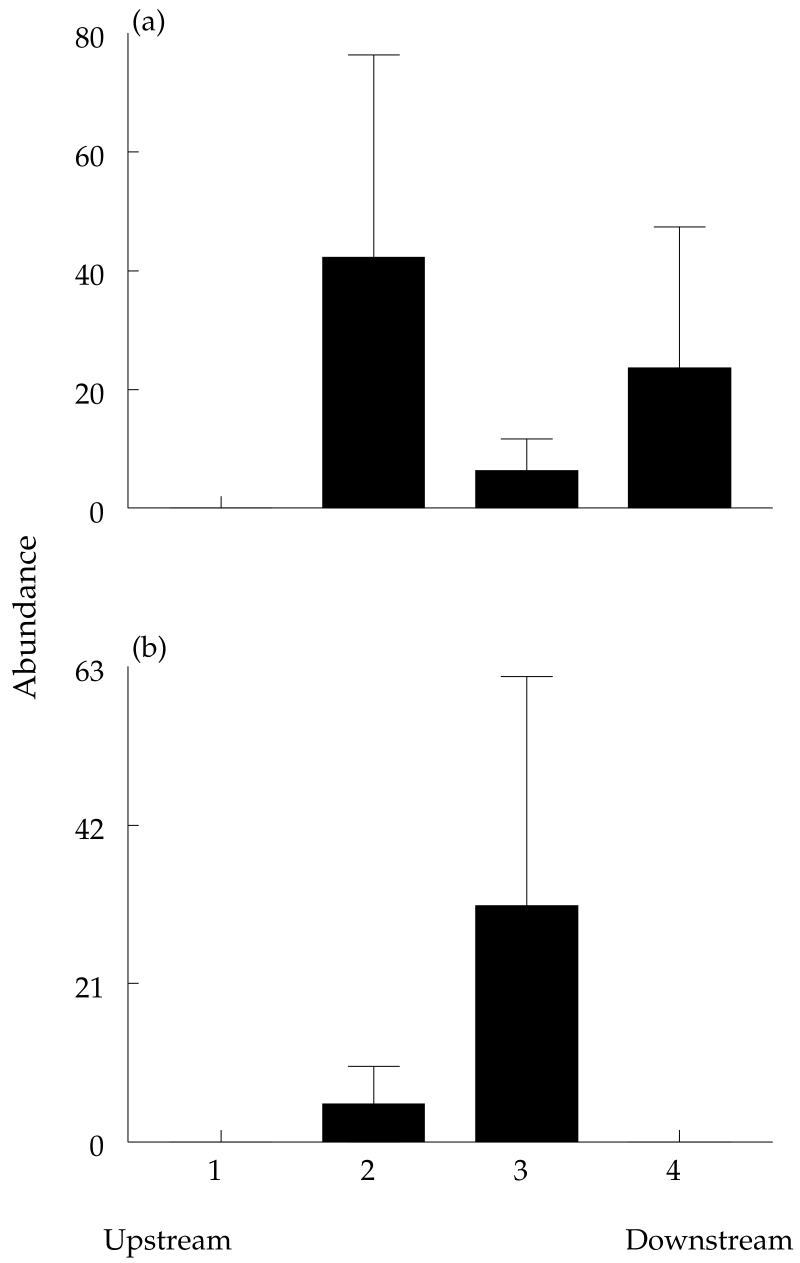


Figure 38. Mean abundance (± SE) of *Herklotsichthys castelnaui* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3).

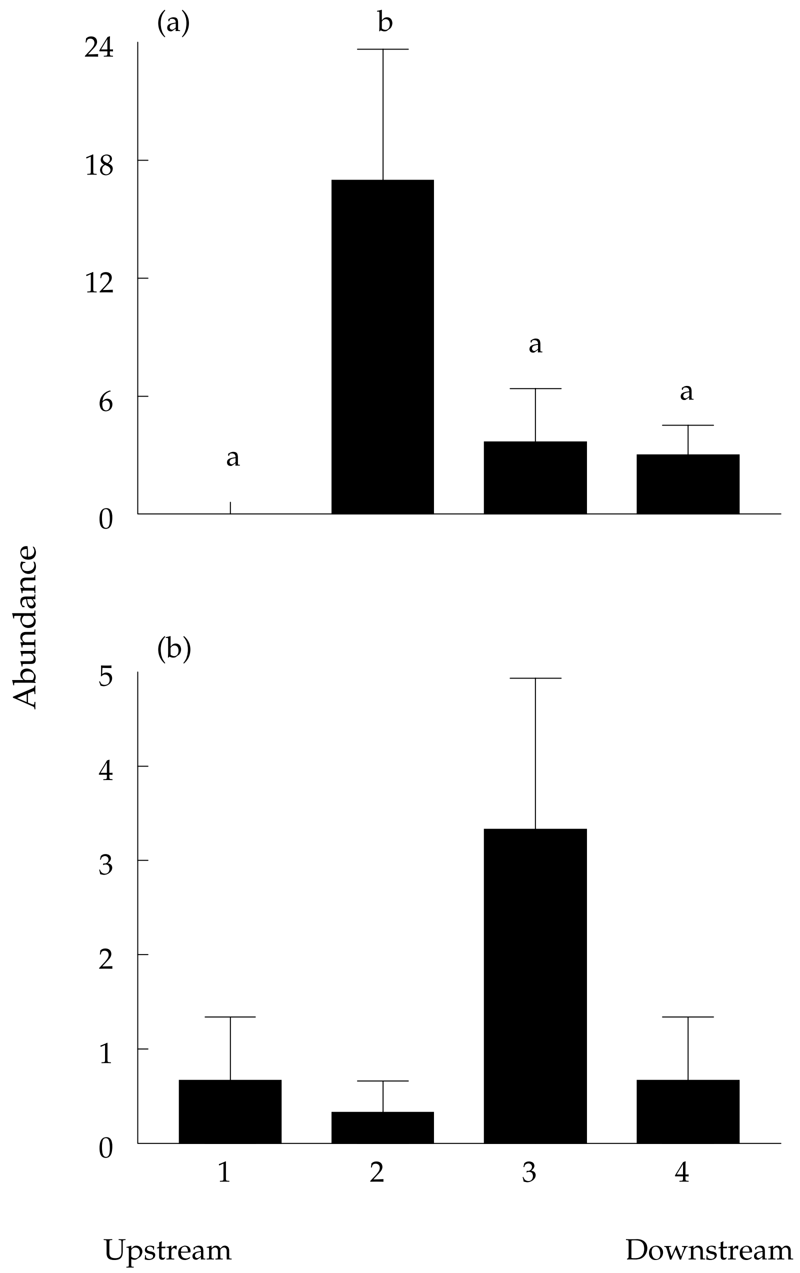


Figure 39. Mean abundance (± SE) of *Leignathus equula* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

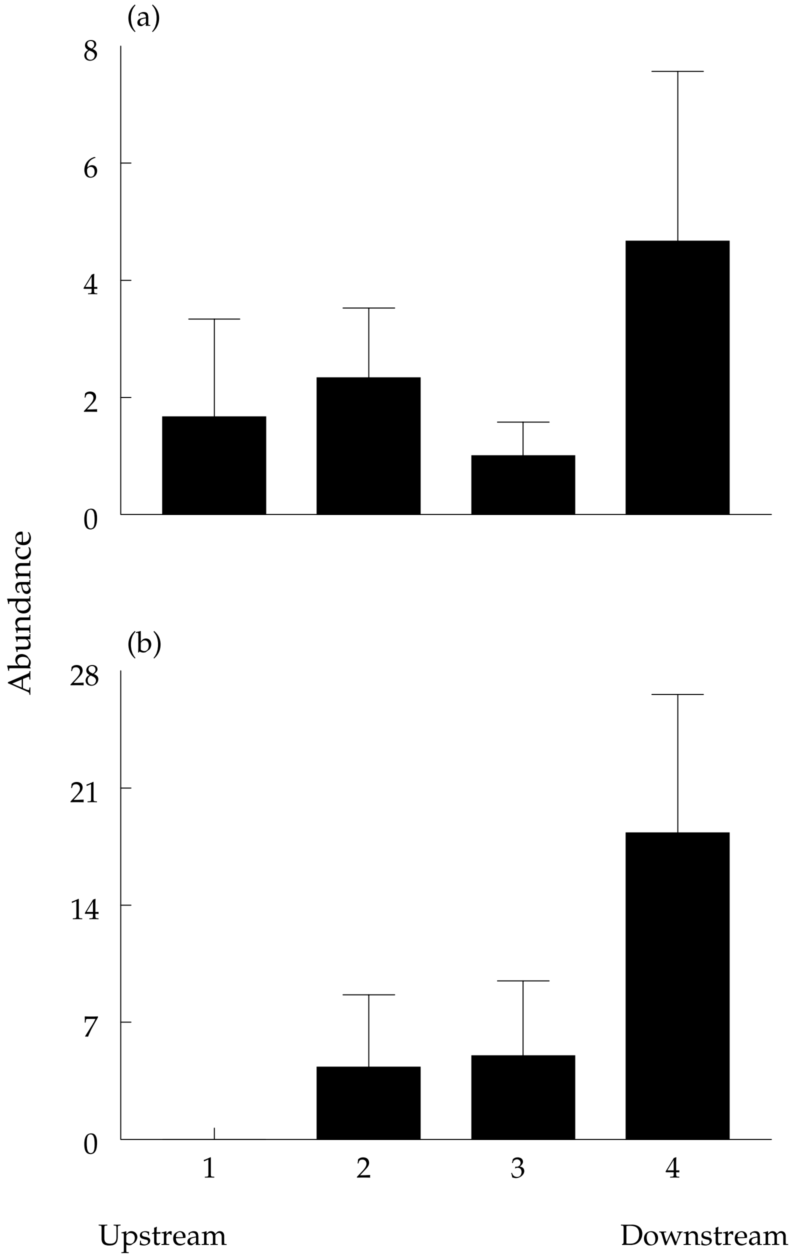


Figure 40. Mean abundance (± SE) of *Gerres subfasciatus* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (*n* = 3).

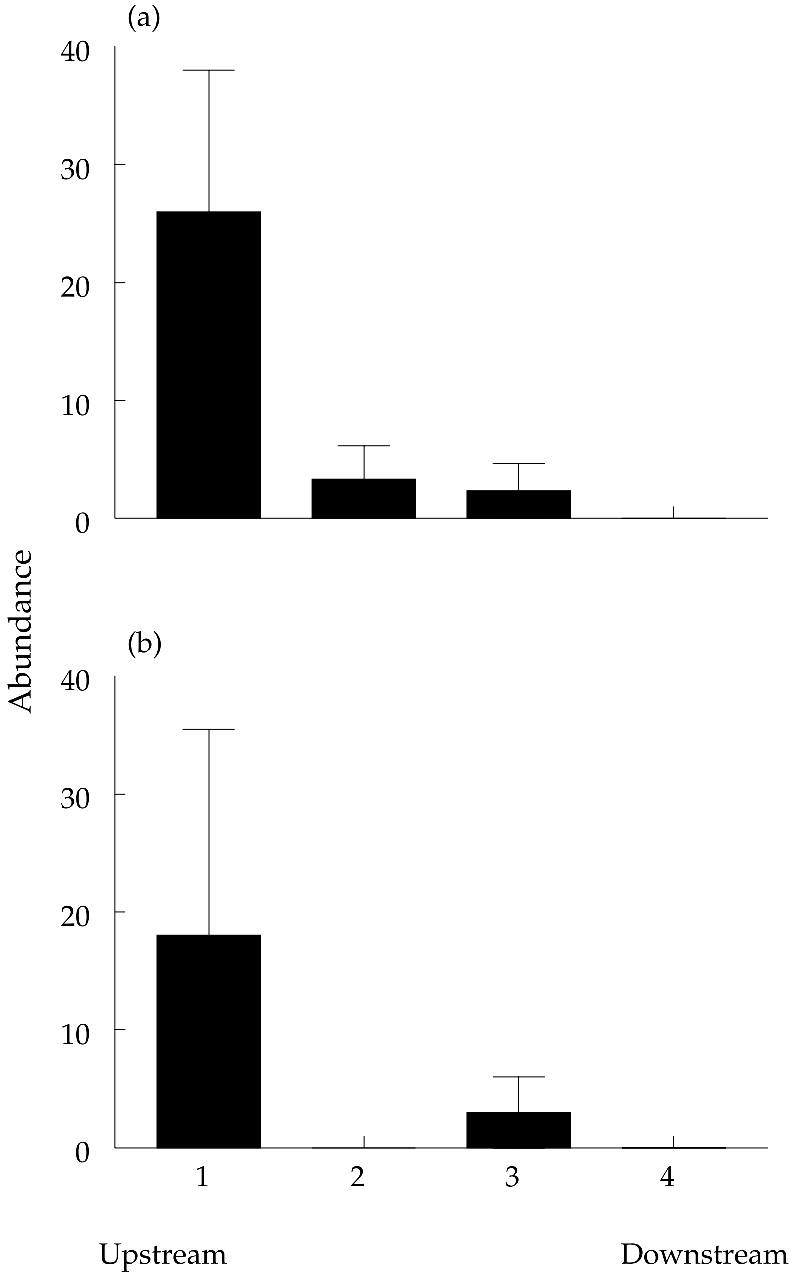


Figure 41. Mean abundance (± SE) of *Hyperlophus vittatus* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (*n* = 3).

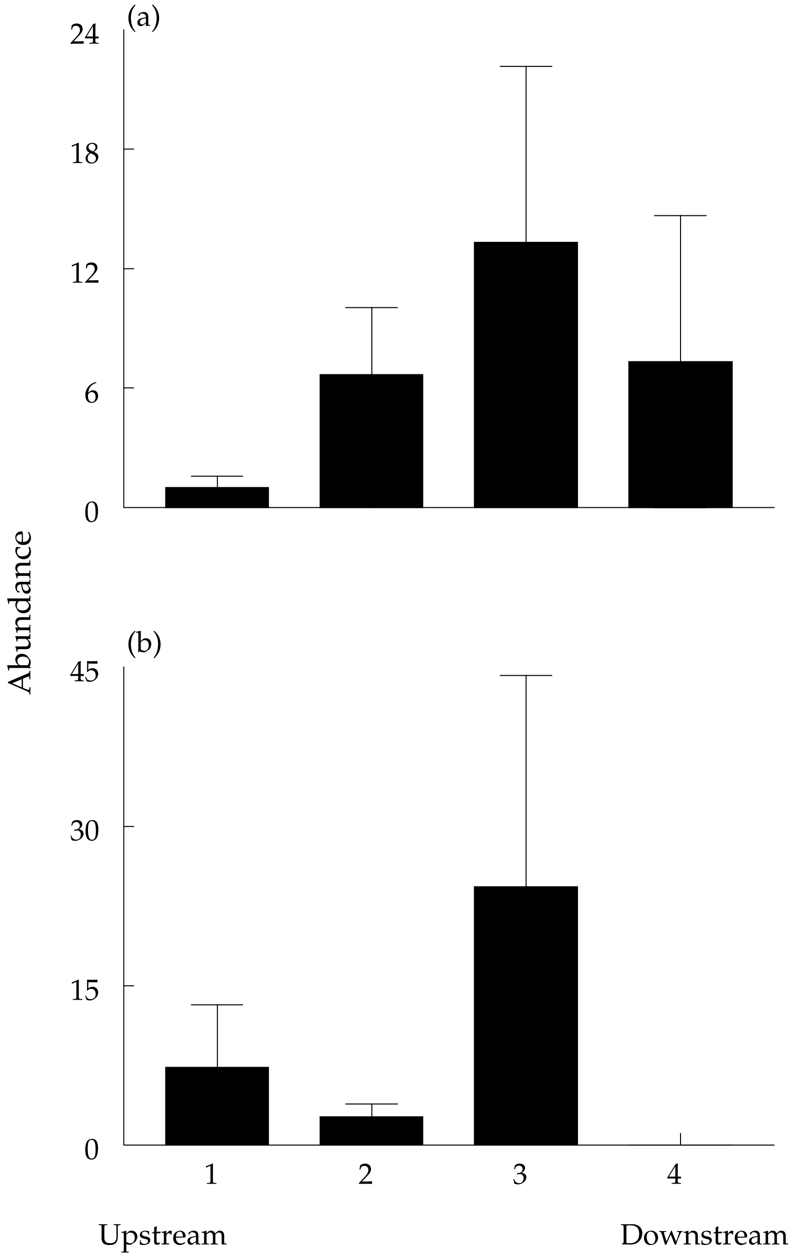


Figure 42. Mean abundance (± SE) of garfish at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3).

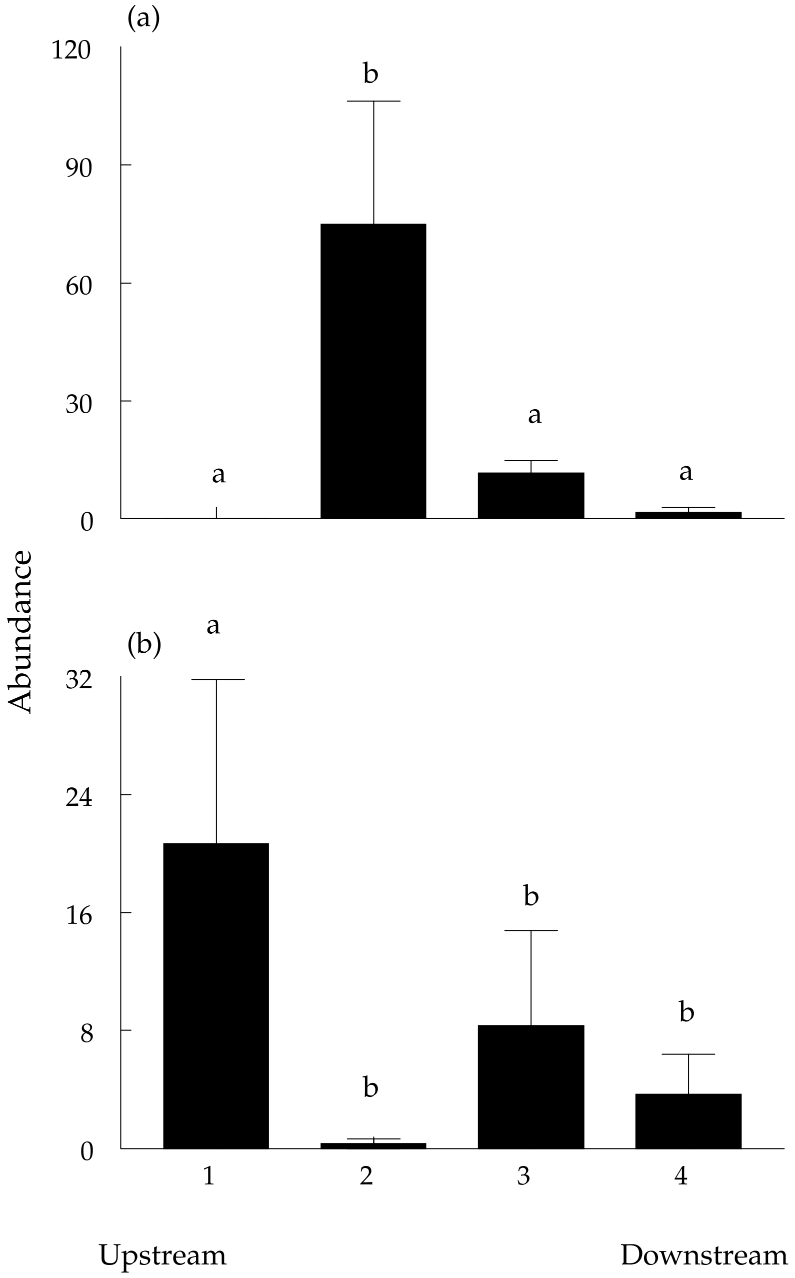


Figure 43. Mean abundance (± SE) of *Sillago maculata* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3). Sites with different letters were significantly different (SNK tests; $p < 0.05$).

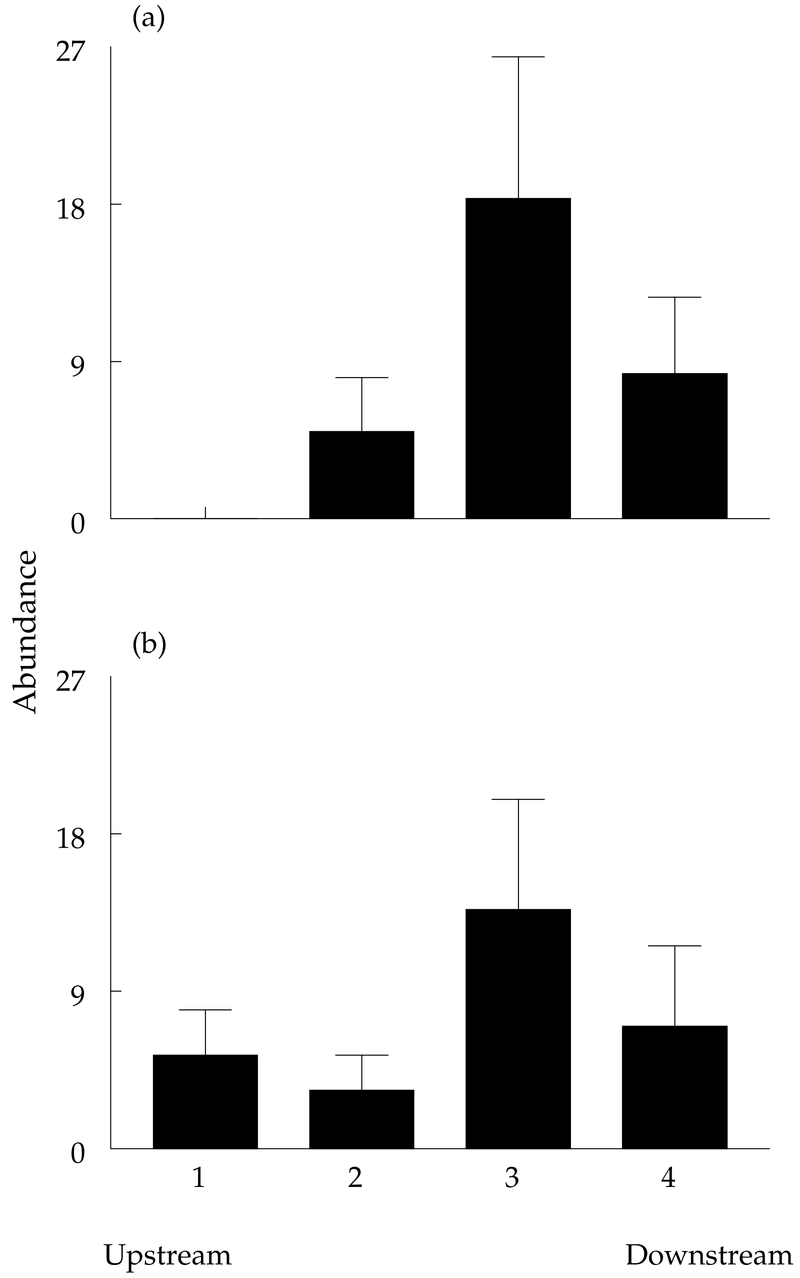


Figure 44. Mean abundance (± SE) of *Tetractenos hamiltoni* at (a) Channel and (b) Flats sites in and adjacent to the navigation channel in the Caboolture River in March 2007 (n = 3).

PLATES

Plate 1. Aerial photographs of key features of the Caboolture River: a) tidal flats on Deception Bay north of Caboolture R.; b) entrance to Caboolture R. looking upstream; c) entrance to Caboolture R. looking towards Deception Bay – note well defined tidal flats; d) large stands of mangroves (m) just upstream of river entrance; e) mud/sand flat adjacent to river channel and mangroves; f) mangroves in middle reach of river (m1 & m2) – m2 is within buffer area on NEBP property.

a.

b.

c.

d.

e.

f.

Plate 2. Aerial photographs of key features of the NEBP and surrounds: a) proposed entrance to the marina (arrow); b) large wetland at western end of NEBP; c) large wetland within NEBP inundated at spring high tide; d) Raff Creek within NEBP at high tide; e) Raff Creek at low tide; f) artificial freshwater pond upstream of NEBP and upstream of tidal influence. NOTE: saltmarsh and mangrove wetlands shown within NEBP in plates b-e occur within proposed buffer areas on NEBP property.

a.

b.

c.

d.

e.

f.

Plate 3. Photographs of key features of the aquatic habitats of the NEBP property: a) entrance from the Caboolture River to small tidal channel at eastern end of property (adjacent to proposed marina entrance); b) mangroves along tidal channel in (a); c) stony culvert across tidal channel, looking “upstream”; d) entrance to Raff Creek from Caboolture River; e) further upstream in Raff Creek, showing muddy banks; f) saltmarshes with mangroves in the background. All wetlands, except (a) & (b) within proposed buffer areas.

a.

b.

c.

d.

e.

f.

Plate 4. Photographs of Caboolture Weir (upstream of NEBP property): a) weir spillway - upstream to the right of plate; b) fishway on downstream, southern side of weir; c) upstream of weir under dry conditions – note extensive macrophytes; d) downstream of weir under dry conditions – no large beds of macrophytes present; e) overtopping of the weir - upstream view - no macrophytes evident; f) overtopping of weir – downstream view.

Plate 5. Photographs of existing infrastructure, Caboolture River): a) commercial marina and slipway downstream of NEBP property, with large stand of mangroves (m1) previously shown in Plate 1f; b) waterfront properties and private berths adjacent to Beachmere Rd and opposite NEBP property; c) water view of same area as shown in (b); d) private boat ramp, mooring piles and erosion control works; e) Caboolture Waste Water Treatment Plant (WWTP) with Caboolture R. in background; f) Burpengary WWTP between Caboolture R. (upper) and Burpengary Ck.

a.

b.

c.

d.

e.

f.

Plate 6. Erosion issues, Caboolture River: a & b) bare river banks with erosion evident in intertidal zone; c) mature mangroves overhanging river; d) pneumatophores (peg roots) of mangroves stabilising the shoreline; e) onsite erosion from unauthorised vehicles; f) car dumped in the Caboolture River on project site upstream of entrance to proposed marina basin.

APPENDICES

Appendix 1. Terms of Reference (ToR) of specific relevance to aquatic ecological issues for the proposed development.

9. **Description of the project.** This includes information relevant to the description of the project, such as:
   a. *Site location in relation to aquatic protected areas (Ramsar, Fish Habitat Area 013 and Moreton Bay Marine Park).*
   b. *Location and extent of the marina precinct.*
   c. *Capital works necessary for upgrading the navigability of the Caboolture River.*
   d. *Extent of vegetation areas and buffer zones in and surrounding the project site*
   e. *Landscaping and rehabilitation proposals.*
   f. *Location and scope of open space areas including public facilities, public and private open space, protected areas and stormwater management areas.*
   g. *Details of sustainability initiatives proposed.*
10. **Ecologically Sustainable Development (ESD)** – to be considered using standard criteria such as defined by the *Environmental Protection Act (Qld)*.
11. **Construction Issues**
   a. *Project Site, with particular emphasis on aquatic habitats and frontage along the Caboolture River.*
   b. *Capital dredging of the navigation channel.*
12. **Operational issues**
   a. *Activities within the marina precinct.*
   b. *Vessel movements within the Caboolture River.*
   c. *Maintenance dredging in the marina basin and navigation channel of the Caboolture River, including methods of minimising dredging plumes and potential release of contaminants on water quality.*
13. **Infrastructure requirements**, including the following matters that are potentially relevant to aquatic ecology:
   a. *Transport issues, including proposed waterway crossings.*
   b. *Water supply and storage, particularly how the possible recycling of water from Council's South Caboolture Sewerage Treatment Plant could benefit the aquatic ecology of the Caboolture River.*
   c. *Stormwater drainage, including the potential concentration of drainage flows into water courses in terms of hydrological and ecological implications for aquatic and fisheries resources.*
   d. *Sewerage, in relation to the potential impact on the nutrient loads being discharged to the Caboolture River and Moreton Bay, as a result of the increase in treated effluent resulting from the proposal.*
14. **Waste management,** including issues associated with groundwater from excavations, rainfall onto disturbed, surfaces and seepages.
15. **Environmental values and management of impacts.** The ToR require a description of existing environmental values in the area that could be affected, with values as defined in the *Environmental Protection Act 1994*, Environmental Protection Policies and other documents such as ANZECC (2000) and the South East Regional Water Quality Management strategy. Values are to be considered in terms of potential adverse and beneficial impacts; potential cumulative impacts, environmental protection objectives and standards, and measurable indicators (evaluated by monitoring and environmental audit) to be achieved; and feasible alternative strategies for managing impacts. Specific matters identified in terms of aquatic ecology include the following:
   a. *Landform, including:*
      i. topography, geomorphology and bathymetry.
      ii. Soils, specifically in relation to Acid Sulphate Soils.

   iii. Sensitive environmental areas, particularly in relation to aquatic reserves, fish habitat areas, sites covered treaties or agreements, etc.
   iv. Potential impacts and mitigative measures, including land contamination and soil erosion.

b. *Water resources, including:*
   i. Surface waterways in terms of water quality and quantity (on a seasonal and event-based scale), existing surface drainage patterns and flows in major streams and wetlands. A description is required, including photographic evidence, of the geomorphic condition of watercourses likely to be affected by disturbance or stream diversion.
   ii. Groundwater
   iii. Potential impacts and mitigation measures, including the development of a water management strategy which considers protection of the integrity of the marine environment, maintenance of sufficient quantity and quality of surface waters to protect existing beneficial downstream uses of those waters (including in-stream biota and the littoral zone).
   iv. Preparation of a risk assessment for uncontrolled emissions to water due to system or catastrophic failure, implications of such emissions for human health and natural ecosystems and provision of strategies to prevent, minimise and contain impacts.

c. *Coastal environment:*
   i. Provide baseline water quality data for the Caboolture River and relevant tributaries downstream of the tidal limit (i.e. Caboolture Weir), including heavy metals, acidity, turbidity and oil in water.
   ii. Discuss the interaction of freshwater flows with marine waters and its significance to marine flora and fauna adjacent to the proposal area.
   iii. Describe coastal resources in terms of values identified in the:
      - *Environment Protection (Water) policy.*
      - *The State Coastal Management Plan 2001.*
      - *The South East Queensland Regional Coastal Management Plan 2006.*
   iv. Describe coastal processes in relation to:
      - Physical and chemical characteristics of sediments in the littoral and marine zones adjacent to the project site.
      - Physical & coastal processes such as currents, tides, storm surges, freshwater flows, bathymetry, sedimentation and erosion, and assimilation and transport of pollutants entering marine waters from the project site.
      - Marine sediments and sediment quality in the area likely to be disturbed by dredging or vessel movements including contamination (e.g. heavy metals, nutrients, pesticides), presence of fines &/or indurated layers and acid sulphate potential. Present this information as a map of sediment types based on their physical and chemical properties, with depth profiles.
      - Environmental values of the coastal resources of the area potentially affected by the project in terms of the physical integrity and morphology of landforms created or modified by coastal processes.
   v. Potential impacts and mitigation measures, including:

- Consistency of the project with the *State Coastal Management Plan 2001* and *The South East Queensland Regional Coastal Management Plan 2006.*
- Potential impacts on tidal hydrodynamics in the Caboolture River, Pummicestone Passage and Deception Bay.
- Potential impacts on bank erosion and adjacent waterways.
- Potential impacts of proposed capital and maintenance dredging, including access to dredge material disposal areas.
- Water quality objectives and practical measures for protecting or enhancing coastal environmental values, including achievement of standards and monitoring, auditing & management of objectives.
- Potential threats to water quality and sediment quality in the Caboolture River associated with construction and operation, including: method and timing of excavation of the marina basin and spoil disposal; potential accidental discharges of contaminants during operation of the marina precinct; release of contaminants from marine structures and vessels, including antifouling coatings; and stormwater runoff from developed areas.
- The role of buffer zones in sustaining fisheries resources through maintaining connectivity between coastal and riparian vegetation and estuarine and freshwater reaches of catchments.
- The potential impact of the proposed project on blooms of the hazardous cyanobacteria *Lyngbya majuscula* in Deception Bay and the Caboolture River (include reference to policy 2.4.7 of *The South East Queensland Regional Coastal Management Plan 2006*).

d. *Noise and vibration*: Assessments in relation to this matter should include environmental impacts on terrestrial and marine animals and avifauna, particularly migratory species. Whilst not included in the ToR, this report also considers impacts on aquatic biota associated with artificial lighting.

e. *Nature conservation*:

i. Environmental values of nature conservation are to be described in terms of:
- Integrity of ecological processes, including habitats or rare and threatened species.
- Conservation of resources.
- Biological diversity, including habitats of rare and threatened species.
- Integrity of landscapes and places including wilderness and similar natural places.
- Aquatic and terrestrial ecosystems, with particular emphasis for this specialist report on waterways, riparian zone, littoral zone and aquatic habitat corridors. Vegetation should be mapped and species listed, and assessed at a local, regional and state scale.

ii. Coastal biodiversity values as mapped or described by the *State Coastal Management Plan 2001* &/or *The South East Queensland Regional Coastal Management Plan 2006* to be identified and an ecological survey and assessment of flora and fauna associated with these areas containing coastal biodiversity values undertaken (to 100 m from these areas).

iii. Identify issues relevant to sensitive areas which may have low resilience to environmental change (e.g. marine environment and wetlands, wildlife breeding areas).
iv. Assess the capacity of the environment to assimilate discharges/emissions and describe proximity of the project site to any biologically sensitive areas.
v. Refer to State and Commonwealth endangered species legislation and proximity of the area to the Great Barrier Reef World Heritage Property.
vi. Describe the occurrence of any pest plants and animals relevant to this specialist report.
vii. Identify key flora and fauna indicators for future monitoring. Where necessary, conduct surveys to reflect possible seasonal variation.
viii. In relation to aquatic ecology, the ToR identify the following tasks:
- Conduct biota studies/surveys in and downstream of the project site if none have been done previously, noting patterns of distribution in the waterways and/or associated marine environments. Include the following:
  - Fish species, mammals, reptiles, amphibians, crustaceans and (other) aquatic invertebrates occurring within the affected area and/or those in the associated marine environment.
  - Identification of types and spatial distribution of economically important fish species, including their migratory requirements.
  - The principal fishes and crustaceans occurring in and adjacent to the project site should be listed, their recreational, traditional and commercial fisheries interest identified and their present abundance and distribution assessed.
  - Any rare or threatened marine species, particularly dugong and its habitat.
  - Define the nature and extent of existing marine features such as littoral and sub-littoral lands, waterways, affected tidal and sub-tidal lands, corals and marine vegetation such as salt couch, seagrass, mangroves within and adjacent to the project site.
  - Aquatic plants (including algal species).
  - Aquatic and benthic substratum.
  - Habitat downstream of the proposal or potentially affected by it.

ix. Potential impacts and mitigation measures:
- Address actions that require an authority under the *Marine Parks Act 1994*, *Nature Conservation Act 1992* and *EPBC Act* and/or would be assessable development for the purposes of the *Vegetation Management Act 1999*.
- Discuss any likely direct and indirect environmental harm due to the project on flora and fauna in any particularly sensitive areas. Consider short term and long term effects of construction,

operation and decommissioning of the project and identify if these effects are reversible or irreversible.

- Describe strategies for protecting the Moreton Bay Marine Park, any rare or threatened species and consider obligations imposed by State or Commonwealth legislation or policy of international treaty obligations (emphasis to be given to benthic and intertidal communities, seagrass beds and mangroves).
- Discuss impacts due to - and mitigation of – alterations to:
    - Local surface and groundwater.
    - Stream or tidal flows and sediment deposition due to dredging with specific reference to benthic environments, fish habitat and migratory bird species using the mouth of the Caboolture River.
- Identify provision of buffer zones and movement corridors.
- Develop a Pest Management Plan where relevant for aquatic ecosystems and include as part of the overall Environmental Management Plan for the project.
- Areas regarded as sensitive with respect to flora and fauna and which should be identified, mapped, avoided or managed to minimise effects include:
    - Areas of nature conservation and interest declared in the Marine Parks (Moreton Bay) Zoning Plan 1997.
    - Fish Habitat Areas as declared under the *Fisheries Act 1994.*
    - Habitats of species listed under the *Nature Conservation Act 1992* &/or *EPBC Act* as presumed extinct, endangered, vulnerable or rare.
    - Regional ecosystems listed as "endangered" or "of concern" under state legislation &/or ecosystems listed under the *EPBC Act* as presumed extinct, endangered, vulnerable or rare.
    - Good representative examples of remnant regional ecosystems which are poorly represented in protected areas.
    - Sites listed under international treaties such as Ramsar or World Heritage.
    - Sites containing near threatened or bio-regionally significant species or essential, viable habitat for such species.
    - Sites in, or adjacent to, areas containing important resting, feeding or breeding sites for migratory species of conservation concern listed under treaty.
    - Sites adjacent to nesting beaches, feeding, resting or calving areas of species of special interest (e.g. marine turtles, cetaceans).
    - Sites containing common species which represent a distributional limit and are of scientific value.
    - Sites containing high biodiversity that are of suitable size or with connectivity to corridors/protected areas to ensure survival in the longer term (e.g. natural habitat in good

condition, such as wetlands; or degraded vegetation or other habitats that still supports high levels of biodiversity or is a corridor for maintaining high levels of biodiversity in the area.
    - A site containing other special ecological values (e.g. high habitat diversity, high area of endemism).
    - Ecosystems providing important ecological functions, such as: wetlands of national, state and regional significance; coral reefs, riparian vegetation, important buffer to a protected area or important habitat corridor between areas.
    - Areas that are proclaimed or are under consideration for proclamation under the *Nature Conservation Act 1992* and *Marine Parks Act 1982*.
    - Areas of major interest, or critical habitat declared under the *Nature Conservation Act 1992* or high conservation areas vulnerable to land degradation under the *Vegetation Management Act 1999*.
- Specific issues to be addressed associated with aquatic ecology include:
    - Assessment of the impact of the project on juvenile and adult aquatic species leading to a loss of productivity in fish, crustaceans, etc.
    - Description of any loss of seagrasses in relation to the extent and regional significance of seagrass communities and associated impacts on fisheries, dugongs, marine turtles, etc.
    - Discuss the impact of the creation of permanent deep water within the marina and likely colonisation of the marina and marine structures.
    - Potential impacts associated with dredging and spoil disposal.
    - Potential impacts associated with altered tidal conditions and degraded water quality.
    - Description of mitigation measures to reduce the impacts on turtles and dugong related to increased recreational and commercial use.
    - Assessment of impacts on Moreton Bay Marine Park and associated Ramsar wetlands through dredging activities and increased marine traffic and visitation.
    - Potential impacts on movements of aquatic species or construction of any waterway barriers (permanent or temporary) and measures to avoid/offset/mitigate these impacts.
- The proposed project should demonstrate consistency with policies of the State Coastal Management Plan &/or the South East Queensland Regional Coastal Management Plan under the topic heading: 2.8 Conserving Nature.

16. **Environmental Management Plan.** The purpose of the EM Plan will be to set out how environmental values will be protected and enhanced as a result of the

project. It should be capable of being viewed as a stand-alone document with the following general contents:

a. *Acceptable levels of environmental performance, including environmental objectives, performance standards and associated measurable indicators, performance monitoring and reporting.*
b. *Impact prevention or mitigation actions.*

Corrective actions to rectify any deviation from performance standards.