Report to:

Tierney Property Services Pty Ltd

&

Cardno (Qld) Pty Ltd

Aquatic Flora & Fauna Survey

Rainbow Beach, Bonny Hills – St Vincents Foundation

April 2008

The Ecology Lab Pty Ltd

Marine and Freshwater Studies

Aquatic Flora & Fauna Survey

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Report Prepared for:

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EXECUTIVE SUMMARY

The Ecology Lab Pty Ltd was engaged by Tierney Property Services Pty Ltd and Cardno (Qld) Pty Ltd on behalf of the St Vincents Foundation to assess the aquatic ecology of an existing water body on a parcel of land at Rainbow Beach, Bonny Hills, on the mid-north coast of NSW. As part of a proposed development concept the Foundation also plans to construct another water body on the land, hence an understanding of the aquatic ecology of the existing water body would assist in predicting conditions likely to develop in the new water body.

Staff from The Ecology Lab visited the site on 8 & 9 January 2008. During the visit, the aquatic habitats of the water body were described and key features photographed. Water quality was measured at the water surface and bottom at four sites using a probe. Sediments were collected at the four sites for examination of organisms living on or just under the sediment surface and fish were sampled using gill nets, bait traps and a small seine net.

The existing water body consists of two interconnected lakes (denoted "E2" and "E3"). Outflow from the larger, eastern lake (E3), is via a small culvert and thence into Duchess Gully, a small creek system running north-south, behind the dunes of Rainbow Beach. At the time of the visit, Duchess Gully was open to the sea and there was some tidal exchange within the lower reaches of the gully. The water body was almost completely fringed by aquatic vegetation, with the Florida torpedo grass (*Panicum repens*), an introduced species, being prominent. Since undertaking this study, much of the torpedo grass has been removed by mechanical means (Tierney, personal communication). Another introduced species, the Cape waterlily (*Nymphaea caerulia*), was also common. In addition, there were numerous native species, including rushes (*Juncus* sp.), cumbungi (*Typha orientalis*), and water primrose (*Ludwigia peploides*) and, submerged within the lake, ribbon weed (*Valissneria nana*). Other workers undertaking site rehabilitation and management of the site have identified numerous other native water plants around the water body.

Surveys of water quality at the site by The Ecology Lab and other workers have shown that the water has electrical conductivities ranging from approximately 0.1 to 0.2 mS/cm). Concentrations of dissolved oxygen were highly variable, ranging from supersaturated (> 110% saturation) to hypoxic (<< 80%). Water depth extends to a maximum of about 3.5 m and, as depth increased, decreases in temperature, redox potential and dissolved levels were recorded, while turbidity readings increased. Generally, pH was within acceptable limits with regard to ANZECC water quality guidelines; however, variable results recorded by The Ecology Lab suggest a faulty pH probe, which casts doubts on results for that indicator at that time. Collection of water samples by other workers indicated elevated concentrations of nitrogen and phosphorous in the water body.

The sediment samples indicated that a small diversity and abundance of invertebrates occur within the sediments on the floor of the water body. Bait traps collected mosquito fish, *Gambusia holbrooki* (introduced), three species of gudgeons, Family Eleotridae (native) and at least two species of freshwater shrimps (F: Atyidae and Palaemonidae, also native). Seining yielded similar species, plus juvenile short finned eels, *Anguilla australis* (native). Large numbers of freshwater shrimps (Atyidae) were also caught in the seine, often where the seine passed through fringing water plants. Gill nets collected two species of fish – sea mullet, *Mugil cephalus* and freshwater mullet, *Myxus petardi* – and one Australian snake-necked turtle, *Chelodina longicolis* (all native). The distribution of one threatened species of

fish, the Oxleyan pygmy perch, *Nannoperca oxleyana*, may extend as far south at the Manning catchment. While the existing water body and Duchess Gully would offer potential habitat for this species, it has not been recorded in the area and is considered unlikely to occur within the site.

During the visit, incidental observations were made of numerous water birds on and around the water body, including chestnut teals, *Anas castanea*, black ducks, *Anas superciliosa*, several species of cormorants, *Phalacrocorax* spp. and swamphens, *Porphyrio prophyrio*. A small islet on the little (western) lake appeared to be a popular roosting area for cormorants. An azure kingfisher, *Alcedo azurea*, was also observed just downstream of the outlet.

The existing water body is considered to be in a relatively healthy condition, on the basis of extensive aquatic habitat, including water plants and moderate fish and bird life. Sea mullet and eels have a marine phase in their life cycle, indicating that those recorded in the water body have been able to migrate from the sea, along Duchess Gully and into the lakes. Maintaining – and possibly enhancing - this connectivity between the lakes and the gully would ensure fish passage into and out of the system. Similarly, the planned location of the proposed water body suggests that it will also be connected to the middle reaches of Duchess Gully and should therefore have potential to be utilised by migratory fishes.

An issue that will need some consideration is water quality within the existing and proposed water bodies. Evidence suggests that elevated nutrients occur within the existing water body, which can lead to eutrophication, including highly variable oxygen concentrations. The lower levels of dissolved oxygen and redox potential at the bottom of the water body may indicate the presence of elevated levels of ammonia there, and may explain the small diversity and abundance of invertebrates in the sediment. It is recommended that further water quality monitoring be done, including sampling of bottom waters and sediment for ammonia. In the longer term, measures should be implemented to minimise runoff of nutrients into the existing and proposed water bodies. Moreover, it is understood that the proposed new urban areas would be developed in accordance with Council policy, hence stormwater quality would be managed to a high standard. Overall, it is likely that the proposed water bodies would function ecologically in a manner similar to the existing ones.

The aquatic ecology of the existing water bodies provides a good basis for the design of the proposed ones. Key issues that should be considered in the design include management of macrophytes (including native and introduced species), implementation of best practice in stormwater management (as is already proposed), minimisation of the potential for water stratification (which could lead to deoxygenation of the bottom water and stress to aquatic fauna), optimisation of connectivity (and hence fish passage) between the water bodies and Duchess Gully and habitat enhancement within the water bodies.

It is recommended that further monitoring of water quality be done in the existing water bodies, including sampling of basic indicators (e.g. temperature, dissolved oxygen, etc) and nutrients. The volumes of water flowing into Duchess Gully from the water bodies should also be determined and any overtopping of the culvert between the water bodies and the gully should be recorded. It is also recommended that the temporary outlet to Duchess Gully be redesigned to facilitate fish passage and that the sampling of fish and invertebrates done as part of this study be repeated, but with greater sampling effort. Finally, sampling of water quality and aquatic fauna would be improved by incorporation of sampling within Duchess Gully.

1.0 INTRODUCTION

1.1 Background and Aims

Tierney Property Services Pty Ltd has been appointed development managers for a proposed development of a parcel of land at Rainbow Beach, Bonny Hills, which is owned by the St Vincents Foundation ("The Foundation"). Cardno (Qld) is consulting to The Foundation regarding engineering matters. The proposed development includes the construction of a large water body, with fill from the water body being used elsewhere on the site. The site currently contains a lake or lagoon system, which is intermittently connected to a small creek (Duchess Gully) during periods of high rainfall and/or very high tides. The Ecology Lab Pty Ltd has been commissioned by Tierney Property Services to undertake a survey of aquatic flora and fauna of the existing lake. This survey would assist in assessing the likely ecological performance of the proposed lake and in designing a monitoring programme for aquatic ecosystems in the proposed water bodies.

The study focused on key ecological components of the lake and the upper portion of Duchess Gully (i.e. downstream of the lake). The aims of the study were to:

- describe aquatic habitats
- describe the distribution of aquatic flora
- report on the occurrence of aquatic invertebrates in the existing water body
- report on the occurrence of fishes in the water body and
- suggest recommendations for designing and managing the proposed new water bodies in terms of aquatic ecology.

This report is due to be included in the Water Engineering and Environment Report being prepared by Cardno (Qld).

1.2 Existing Information

1.2.1 Water Quality

Tierney Property Services provided The Ecology Lab with a report on previous investigations of water quality in the water body (Coffey 2008). Data for two investigations were presented in Coffey (2008), including a survey done by Coffey from September to December 2007 and one done by Chandler Geotechnical Pty Ltd from November 2005 to February 2006. For both studies, a water quality probe was used to measure indicators at 0.5 m depth intervals at one location within the water body. In addition, water samples were collected, presumably from the surface, for analysis of total nitrogen and total phosphorus. Coffey also analysed water for turbidity and Chlorophyll-a. The exact location of the sampling station(s) was not provided in Coffey (2008).

Data obtained using probes are reproduced in this report in Appendix 1 and compared to ANZECC (2000) guidelines for the protection of aquatic ecosystems. Water temperature typically decreased as depth increased (Appendix 1a), with some variation by over 7 $^{\circ}$C within a 3.5 m depth range (e.g. 11/12/2007). pH was generally within ANZECC guidelines, usually ranging from about 6.5 to 7.5 pH units (Appendix 1b). Several readings were just at or below the ANZECC guideline of 6.5.

Electrical conductivity ranged, on average, from 0.152 to 0.268 mS/cm (Appendix 1c). Electrical conductivity was variable both with depth and time of sampling (Appendix 1d). At some times there were slight increases with depth (e.g. 29/9/05 & 17/11/05); at other times there were decreases (e.g. 31/10/07 & 11/12/07).

Dissolved oxygen showed large variability, ranging from supersaturated (> 110%) to hypoxic (<< 80% - Appendix 1e). In some instances large decreases with depth were recorded for DO (e.g. 29/9/05, 31/10/07, 27/11/07 & 11/12/07).

Analysis of water samples collected previously (Coffey 2008) is summarised in Appendix 2. Turbidity of surface water was generally within the ANZECC guidelines (Appendix 2a). Total nitrogen and total phosphorous exceeded the guidelines for all samples (Appendix 2a & b). Chlorophyll-a equalled or exceeded the guideline in three of the eight Coffey samples (Appendix 2a).

1.2.2 Threatened Aquatic Species

An important consideration in recent ecological studies has been the presence of threatened species and many aquatic species have been declared as threatened under state legislation (*Threatened Species Act* 1996; *Fisheries Management Act* 1994) or Commonwealth legislation (*Environment Protection Biodiversity Conservation Act* 1999). One species that potentially may be affected by developments on the north coast of NSW is the Oxleyan pygmy perch (*Nannoperca oxleyana*), a small, relatively cryptic fish that occurs in coastal lakes and lagoons. The range of this species is considered to extend potentially as far south as the Manning River, but it has not been reported from water bodies in the vicinity of Port Macquarie-Laurieton. On this basis, it was concluded that this species does not require detailed consideration in relation to the current study.

2.0 STUDY METHODS

The site was visited on 8 & 9 January 2008 (Figure 1). At that time, there had been extensive rainfall on the NSW north coast and very rough seas. During the visit, weather was generally cloudy, with south easterly winds and intermittent rain. Two staff from The Ecology Lab walked around much of the perimeter of the subject water body. We also walked from the outflow along a channel to the confluence with Duchess Gully and later inspected the mouth of Duchess Gully at Rainbow Beach. During the time of the survey the gully was open to the sea over the beach berm, with some penetration of sea water due to wave wash and tides. Photographs were taken of relevant features and records made of aquatic and riparian habitats, including aquatic plants.

A small boat was launched on the water body to gain access to the deeper areas. A calibrated water quality probe (Yeo-cal) was used to measure temperature, electrical conductivity (EC – an indicator of the concentration of dissolved salts), pH, dissolved oxygen, (DO as mg/L and % saturation) oxidation reduction potential ("redox" - ORP) and turbidity (ntu). At the time, pH readings were highly variable and unstable indicating a faulty sensor. Thus, whilst the data for pH are reported here, we consider them to be suspect. Water quality was measured at four sites on the subject water body (Figure 2). At each site, two replicate readings each were taken at the surface and just above the bottom.

Sediments were collected by a diver using snorkelling gear. The cores were taken using a short piece of pvc pipe (100 mm diameter) gently pushed 20 cm into the substratum. Two replicate cores were collected at a depth of about 2 m at four sites (Figure 2). The sediment was sieved through a 1 mm mesh and preserved in 10% formalin stained with Bengal scarlet. The samples were then returned to the laboratory and sorted and identified using a binocular microscope.

Fish were sampled using three standard survey methods. First, small, baited traps were set on the floor of the water body, very close to the shore and hence in or near aquatic plants. The bait comprised a mash of chicken pellets and sardines and traps were set for 2 - 3 hours during the middle of the day. A minimum of two traps were set at each of four sites (Figure 2). Several traps were also set in the outlet channel. Animals collected in the traps were identified and counted and then released, apart from a few specimens kept to verify the field identifications.

Second, a small seine net (10 m long x 1.5 m deep, with 2 mm mesh) was deployed at three locations around the big lake within the water body. The use of the seine was limited to these locations due to the dense growth of aquatic plants around the water body. Thus, we were able to find only three suitable locations for seining. However, this method had the advantage of sweeping through some of the less dense macrophytes, which enhanced the sampling by capturing species that shelter among the fronds of macrophytes.

Finally, gill nets were set at four sites around the water body, including three nets in the big lake and one in the small lake (Figure 2). Each net was 60 m long and comprised two, 30 m lengths of 100 mm and 50 mm monofilament mesh, approximately 1.5 m deep. The nets were set for approximately three hours, but were checked approximately every 30 to 40 minutes. Fish were removed from the net, identified, counted and measured to fork length (LCF, mm) and released.

During the visit, many water birds were observed on or around the water body. Where possible, birds were identified and their position in relation to the water body noted.

3.0 RESULTS

3.1 General Description of Habitats

The subject water body comprises two lakes (Figure 1). The larger lake (E2) is on the eastern side and contains the outlet to Duchess Gully. The outlet passes through a small culvert comprising a small pipe encased in concrete, which forms a low weir (Plate 1a - c). The water level of the water body can be regulated somewhat by a swivelling pvc pipe which can be adjusted in relation to the water levels of the water body (Plate 1b). This configuration, which is temporary, would allow passage of small fish and invertebrates from the water body into Duchess Gully. It would, however, limit upstream movement unless the weir is overtopping, which does occur from time to time (Tierney Property Services, personal communication). Below the outlet there is a relatively broad channel (4 – 6 m wide) flowing to Duchess Gully (Plates 1 d, e,; and 2a). Between the two lakes of the water body is a small channel ((< 0.5 m wide) fringed by a dense growth of torpedo grass (Plate 1f). During the visit water was flowing from the small lake (E2) into E3. A stormwater treatment area (E1) treats some, but not all, stormwater entering the water bodies.

Duchess Gully flows over a wide beach berm at Rainbow Beach (Plate 2b, c). Water throughout the system was dark brown during the visit, possibly reflecting tea-tree staining following rainfall. A waste water treatment plant (WWTP) occurs to the east of the subject water body and adjacent to Duchess Gully (Figure 1). There are ponds associated with the WWTP; these appear to be "downhill" of the water body.

3.2 Water Quality

Data collected using the probe are presented in Table 1 and Figure 3. The data indicate variability among sites within the water body and with depth. Temperature was always slightly less at the bottom than the surface (Figure 3a). Conductivities (not graphed) were around 0.2 mS/cm, which is consistent with earlier studies (Appendix 1). pH was generally low, with higher values at Site 4 (Figure 3b). As noted above, results for pH may be unreliable due to a faulty sensor. ORP was generally relatively low and positive at sites 1 – 3, but strongly negative at Site 4, indicating a reducing environment (Figure 3c). Concentrations of dissolved oxygen were generally low, and always less at the bottom than the surface (Figure 3d). Finally, turbidity was always substantially greater at the lake bottom than the surface (Figure 3e).

3.3 Aquatic Flora and Fauna

As noted previously, the water body was fringed by dense growth of aquatic plants, primarily torpedo grass. Notwithstanding the dominance of this species, there were numerous other species recorded at the site, both during the site visit and by other workers (Table 2, Plate 3). During the visit we observed areas of dense growth of a submerged plant, identified as *Vallisneria nana*, which was prevalent at the western end of E3 and in parts of E2.

From the eight cores of sediment collected, only three invertebrates were collected, which indicates very small abundances of invertebrates within the sediment (Table 3).

Bait traps collected mosquito fish (introduced), three species of gudgeons (native) and at least two species of freshwater shrimps (Table 4). Seining yielded similar species to the bait traps, plus two juvenile short finned eels. Large numbers of freshwater shrimps were also caught in the seine, often where the seine passed through fringing water plants (Table 4, Plate 4). Gill nets collected two species of fish – sea mullet and freshwater mullet – and one turtle (Table 4, Plate 4). No Oxleyan pygmy perch were recorded.

Six species of water birds were observed on the water bodies, while an azure kingfisher, *Alcedo azurea* was observed just downstream of the confluence of the outflow with Duchess Gully (Table 5). Ducks were very prominent on E3 (particularly chestnut teals, *Anas castanea*) and cormorants (*Phalacrocorax* spp.) were observed roosting on a small islet on E2.

4.0 DISCUSSION

4.1 Aquatic Habitats

Key features of the aquatic habitats of the existing water bodies are the extensive growth of macrophytes around and within the water bodies, and connectivity between the water bodies and with Duchess Gully. Whilst torpedo grass, an introduced species, was prominent during the field investigations, other specialists evaluating the best way in which to manage the species have recently undertaken removal by mechanical means (Tierney

Property Services, personal communication). The connectivity means that several species that live in fresh or brackish waters but complete their life cycle in estuaries or the sea can access the water bodies, which helps to improve the biodiversity of the system (see below).

4.2 Water Quality

Concentrations of dissolved oxygen were below the ANZECC (2000) water quality guideline in all bottom samples taken, while the surface samples were at or just below the guideline. Conductivity exceeded the ANZECC (2000) guideline for freshwater lakes and reservoirs. This guideline, however, is considered to be very conservative in the context of the study location, given that the guideline is applicable to a broad range of lacustrine habitats, including relatively pristine waters of Tasmanian lakes (Table 3.3.3 in ANZECC 2000). In the current study, both water bodies occur very close to Duchess Gully, which can have tidal penetration and hence may, at times, penetrate the water bodies. There may also be some intrusion of salt into the water bodies via groundwater. Moreover, our survey identified several species of fish that can occur readily in waters with variable conductivity.

Evidence suggests elevated nutrients occur within the existing water body, which can lead to eutrophication and highly variable oxygen concentrations. The lower levels of dissolved oxygen and redox potential at the bottom of the water body may indicate the presence of elevated levels of ammonia there and may explain the small diversity and abundance of invertebrates in the sediment. Sampling of bottom waters and sediment for ammonia would confirm this prediction. In the longer term, it is understood that measures would be implemented in minimise runoff of nutrients into the existing and proposed water bodies (Tierney Property Services, personal communication).

4.3 Aquatic Flora and Fauna

Broadly, the existing water body is considered to be in a relatively healthy condition, on the basis of extensive aquatic habitat, including water plants, and moderate fish and bird life. Sea mullet and eels have a marine phase in their life cycle, indicating that those recorded in the water body have been able to migrate from the sea, along Duchess Gully and into the lakes. Maintaining – and possibly enhancing - this connectivity between the lakes and the gully would ensure fish passage into and out of the system. Similarly, the planned location of the proposed water body suggests that it will also be connected to the middle reaches of Duchess Gully and should therefore have potential to be colonised by migratory fishes.

4.4 Considerations for the Design of the Proposed New Water Bodies

Based on the field investigations and understanding of the proposed new water bodies at the site, the following matters should be considered in designing the proposed new water bodies:

1. Plant and/or promote the growth of native macrophytes, including fringing and submerged species.
2. Prevent/inhibit the growth of any pest species of macrophytes, especially torpedo grass.
3. Implement best practice in stormwater management to ensure water of an appropriate standard to support aquatic ecosystems is maintained in the water bodies.

4. Design the new water bodies to minimise the potential for stratification of the water column, which could lead to deoxygenation of water at the bottom of the water bodies and consequent stress on biota living just above, on and within the substratum.
5. Design the outlet of the water bodies into Duchess Gully to allow passage of fauna between the water bodies and the gully.
6. Provide additional structure within the water bodies to enhance biodiversity. Examples include:
    a. Creation of small islets as roosting and nesting areas for water birds.
    b. Emplacement of small amounts of fallen timber within the water bodies (and possibly emerging just above the water surface) to provide additional habitat for fish, aquatic reptiles and aquatic invertebrates.
7. Consider, in consultation with NSW Department of Primary Industry, stocking the water bodies with native species, such as Australian bass (*Macquaria novemaculeata*). This fish is a popular angling species common in NSW coastal rivers (including the Manning and Hastings rivers). It has been stocked into a number of reservoirs and may provide a recreational outlet for local residents.

5.0 RECOMMENDATIONS

This study provides a preliminary understanding of the aquatic ecology of the existing water bodies. As such, it provides a valuable focus for the design of the proposed water bodies and assists in defining meaningful ecological indicators for future monitoring. It does not, however, provide a baseline for assessing changes in future and further work would be required to obtain such a baseline. The following actions are recommended with respect to aquatic ecology and should be considered in the context of Section 4.4, which relates specifically to the proposed new water bodies:

1. Undertake ongoing monitoring of water quality in the existing lakes. This should include sampling basic indicators (temperature, dissolved oxygen, pH, conductivity, redox potential and turbidity) in surface and bottom waters within at least two sites (preferably 3 to 4 sites) each in E2 and E3. It is suggested that regular (e.g. fortnightly) and event-based (i.e. after heavy rainfall) sampling be initiated. It would also be beneficial to establish two or more sampling stations within Duchess Gully, including sites upstream and downstream of the confluence of the gully with the outlet from the existing water bodies.
2. Collect water samples from the existing water bodies for analysis of nutrients, including total nitrogen, ammonia, nitrogen oxides (NOx), total phosphorous and orthophosphates. At least two samples should be collected at both the surface and bottom from at least two sites each in E2 and E3.
3. Determine the volume of flows of water between E2 and E3, and between E3 and Duchess Gully. Record the date and duration of overtopping events at the E3/Duchess Gully culvert, along with climatic conditions at the time.
4. Continue ongoing management of torpedo grass and establishment of native macrophytes.

5. Redesign the existing, temporary outlet to Duchess Gully to facilitate fish passage between the water bodies and the gully. Similarly, design the outlet of the proposed new water bodies to optimise fish passage.
6. Implement appropriate management of stormwater (as is currently proposed by the proponent).
7. Repeat the sampling of invertebrates and fish as undertaken for the present study. It is recommended that samples be taken on at least three more occasions to provide a baseline for measuring future change. It would also be beneficial to:
   a. Increase the number of sample sites and replicates (i.e. cores and bait traps) to provide more precise estimates of abundance and taxon richness for aquatic fauna.
   b. Undertake some sampling in Duchess Gully to measure differences, if any, in biodiversity and abundance between the water bodies and the gully. This would provide an indication of the effectiveness of connectivity between the water bodies and the gully and/or the suitability of habitat within the water bodies.
   c. Investigate and, if feasible, incorporate, reference locations to provide a measure of background variability independent of the existing and proposed developments. This would enhance the baseline of data for measuring future changes in the existing and proposed water bodies.

6.0 ACKNOWLEDGEMENTS

Field work was done by Dr Marcus Lincoln Smith and Matthew Birch. Laboratory sorting and identification of sediment was done by Dr Rad Nair, Bob Hunt and Rick Johnson. Identification of fish and decapods was done by Marcus Lincoln Smith and Brendan Alderson. This report was written by Marcus Lincoln Smith.

7.0 REFERENCES

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TABLES

Table 1. Water quality indicators measured at subject waterbody, 8 January 2008 between 15:30 and 16:30. GPS positions recorded in WGS84 datum, UTS/UTM projection. Note, values in bold are outside ANZECC (2000) water quality guidelines for protection of aquatic ecosystems.

Station - No. & description	GPS		Sample	Depth of measurement (m)	Water quality indicator						
					Temp. C	Conductivity mS/cm	pH	ORP mV	DO%	DO mg/L	Turbidity ntu
Site 1: Near Causeway (Big Lake)	0484187	6506650	1	Suface	28.76	**0.2**	**4.02**	45	**76.5**	5.9	5.8
			2	Suface	28.93	**0.2**	**3.98**	22	80.1	6.1	4.9
				Mean:	28.85	**0.20**	**4.00**	33.50	**78.30**	6.00	5.35
				SE:	0.08	0.00	0.02	11.50	1.80	0.10	0.45
			1	2.5	28.60	**0.2**	**4.00**	31	**72.5**	5.5	**20.3**
			2	2.5	24.43	**0.2**	**4.03**	83	**30.1**	2.6	**67.6**
				Mean:	26.52	**0.20**	**4.02**	57.00	**51.30**	4.05	**43.97**
				SE:	2.09	0.00	0.02	26.00	21.20	1.45	23.63
Site 2:	0484168	6506644	1	Suface	28.00	**0.2**	**4.00**	10	**71**	5.5	6.8
Little Lake			2	Suface	27.87	**0.3**	**3.97**	10	**69.5**	5.4	6.3
				Mean:	27.94	**0.25**	**3.99**	10.00	**70.25**	5.45	6.57
				SE:	0.06	0.05	0.01	0.00	0.75	0.05	0.27
			1	1.5	24.86	**0.2**	**4.03**	29	**21.5**	1.8	**62.0**
			2	1.5	24.76	**0.3**	**4.02**	37	**23.2**	1.3	**50.4**
				Mean:	24.81	**0.25**	**4.03**	33.00	**22.35**	1.55	**56.20**
				SE:	0.05	0.05	0.01	4.00	0.85	0.25	5.80
Site 3: Near stormwater outlet, S side of big lake	0484468	6506480	1	Suface	28.93	**0.2**	**4.01**	-41	**77.8**	6.0	7.7
			2	Suface	28.95	**0.2**	**3.96**	13	**75.6**	5.9	6.5
				Mean:	28.94	**0.20**	**3.99**	-14.00	**76.70**	5.95	7.08
				SE:	0.01	0.00	0.02	27.00	1.10	0.05	0.58
			1	2.5	24.58	**0.2**	**4.05**	28	**37.1**	3.1	**68.2**
			2	2.5	24.65	**0.2**	**4.01**	66	**26.4**	2.2	**56.5**
				Mean:	24.62	**0.20**	**4.03**	47.00	**31.75**	2.65	**62.38**
				SE:	0.04	0.00	0.02	19.00	5.35	0.45	5.85
Site 4: Near outlet to Duchess Gully from big lake	0484538	6506583	1	Surface	29.14	**0.2**	7.38	12	82.8	6.4	**38.8**
			2	Surface	29.28	**0.2**	**10.30**	-54	**75.9**	5.8	16.3
				Mean:	29.21	**0.20**	**8.84**	-21.00	**79.35**	6.10	**27.55**
				SE:	0.07	0.00	1.46	33.00	3.45	0.30	11.28
			1	2.5	22.46	**0.3**	7.39	-325	**5.4**	0.6	**98.1**
			2	3.5	22.91	**0.3**	7.64	-347	**4.2**	0.4	**104.9**
				Mean:	22.69	**0.30**	7.52	-336.00	**4.80**	0.50	**101.52**
				SE:	0.22	0.00	0.13	11.00	0.60	0.10	3.42

Table 2. Aquatic plants observed at subject water bodies.

Species	Royal Botanic Garden identifications	Staff observations on-site	Observations by The Ecology Lab
Nymphaea caerulea (introduced species)	x		x
Eleocharis equisitina	x		
Potamogeton javanicus	x		
Triglochin sp., juvenile specimen	x		
Baumea juncea	x		
Chorizandra sphaerocephala	x		
Schoenus brevifolius	x		
Ludwigia peploides subsp. *montevidensis*	x		x
Persicaria decipiens	x		
Fimbristylis tristachya	x		
Fimbristylis dichotoma	x		
Lepyrodia muelleri	x		
Baloskion pallens	x		
Baumea teretifolia	x		
Lepidosperma quadrangulatum	x		
Juncus prismatocarpus	x	x	
Baumea articulata		x	x
Baumea rubiginosa		x	
Cyperus polystachyos		x	
Eleocharis spacelata		x	
Juncus krausii			
Juncus usitatus			
Philydrum lanuginosum			
Schoenus brevifolius			
Typha orientalis			x
Valissneria nana			x
Pannicum repens (introduced species)		x	x
Eleocharis sp.			x

Table 3. Benthic invertebrates sampled using diver-operated cores, 8 January 2008. Sites at approximately the same positions as water quality measures (see Table 1).

Invertebrate Group	Family	Site 1		Site 2		Site 3		Site 4	
		Core 1	Core 2	Core 1	Core 2	Core 1	Core 2	Core 1	Core 2
Polychaete worm	Capitellidae		2						
Gastropod mollusc	Anabathronidae								1

Table 4. Fish, invertebrates and reptile sampled using bait traps, beach seine and gill nets in subject waterbody, 9 January 2008.

a. Bait Trap and Beach Seine catches

Species		Method																						
Common name	Scientific name	Bait Traps																			Beach Seine			
		BT - Site 1			BT - Site 2				BT - Site 3			BT - Site 4			BT - Site 4a		BT - Site 4b			**Total**				**Total**
		BT1	BT2	BT3	BT1	BT2	BT3	BT4	BT1	BT2	BT3	BT1	BT2	BT3	BT1	BT2	BT1	BT2	BT3		BS1	BS2	BS3	
Shortfin Eel	*Anguilla australis**																			**0**	2			**2**
Empire Gudgeon	*Hypseleotris compressus*					3			5			4	1		2	1	1	6	5	**28**				**0**
Striped Gudgeon	*Gobiomorphus australis*								2							18		2	2	**24**	2		1	**3**
Flathead Gudgeon	*Philypnodon grandiceps*				2							1	2	1	1	48				**55**	44	25	8	**77**
Mosquito Fish	*Gambusia holbrooki*															81				**81**	17	27	15	**59**
Atyid Shrimp	Family: Atyidae																		1	**1**	3	540	214	**757**
Palaemonid shrimp	*Macrobrachium* sp.														2	1		1	1	**5**				**0**
	Totals:	0	0	0	4	6	0	0	14	0	0	10	6	2	10	298	2	18	18	**388**	136	1184	476	**1796**

* Total Lengths: 60 and 80 mm

b. Gill Net catches

Common name	Scientific name	Gill net samples				
		Number caught				Length(s) - fork length (LCF, mm)
		1	2	3	4	**Total**	
Sea Mullet	*Mugil cephalus*	6	4	2		**12**	305, 298, 285, 298, 246, 490, 420, 415, 330, 350, 295
Freshwater Mullet	*Myxus petardi*	1				**1**	376
Snake-necked turtle	*Chelodina longicolis*		1			**1**	-

Table 5. Water birds observed at subject water body.

Species	Common name
Alcedo azurea	Azure kingfisher
Anas castanea	Chestnut teal
Anas superciliosa	Pacific black duck
Porphyrio porphyrio	Purple swamphen
Phalacrocorax carbo	Black cormorant
Phalacrocorax melanoleucos	Pied cormorant
Phalacrocorax sulcirostris	Little black cormorant

FIGURES

Figure 1. Aerial photograph showing subject site and surrounding features. WWTP = Waste Water Treatment Plant. Blue arrow shows direction of flow of water in Duchess Gully towards the sea. Source of Photo – Tierney Property Services (January 2008).

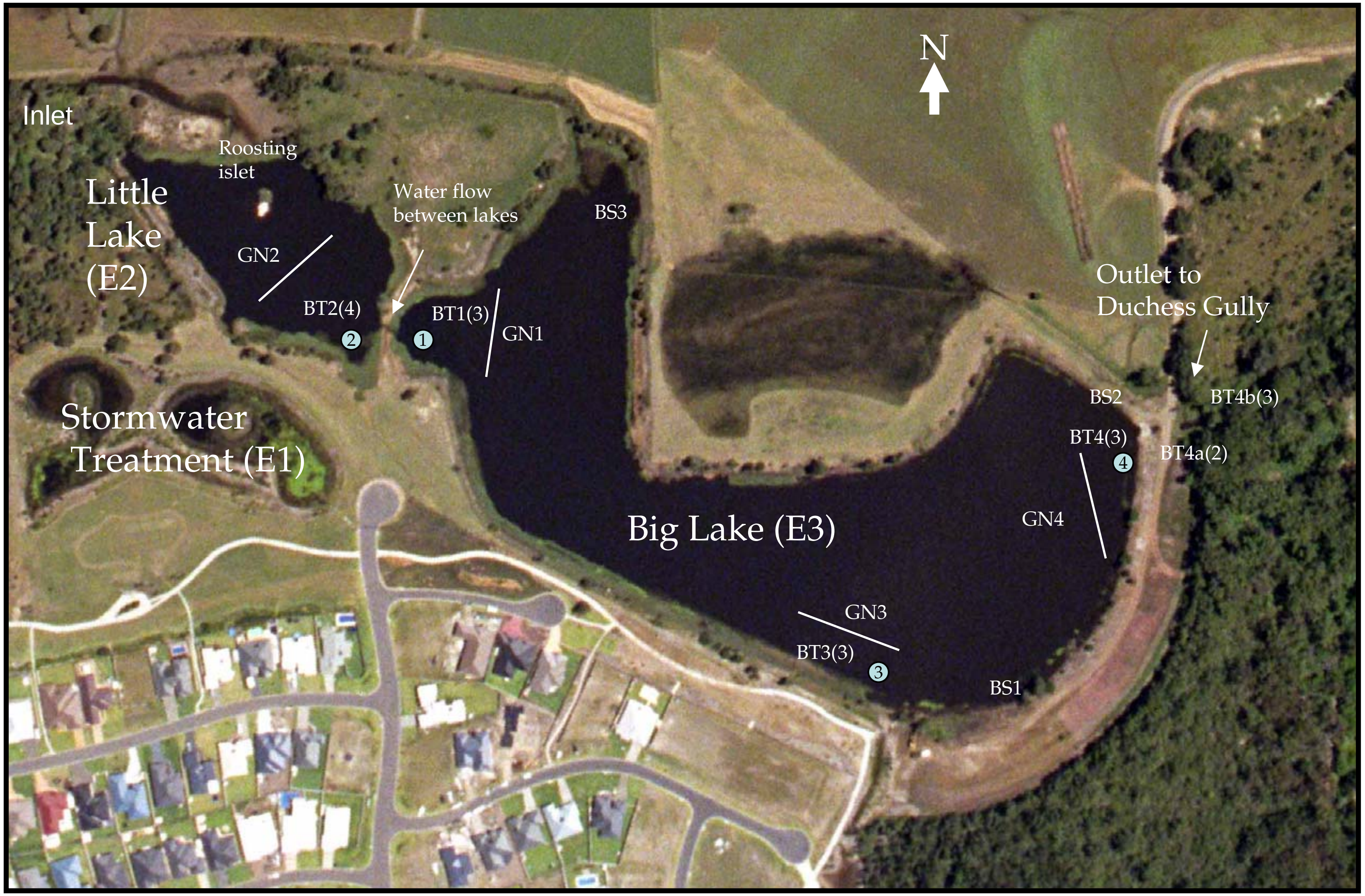

Figure 2. Aerial photograph showing sampling sites in January 2008. Blue circles with numbers = sites of benthic cores (2 cores per site); BT = Bait Trap sites (brackets show number of traps deployed); BS = Beach Seine sites; GN = Gill net sites. Source of Photo – Tierney Property Services (January 2008).

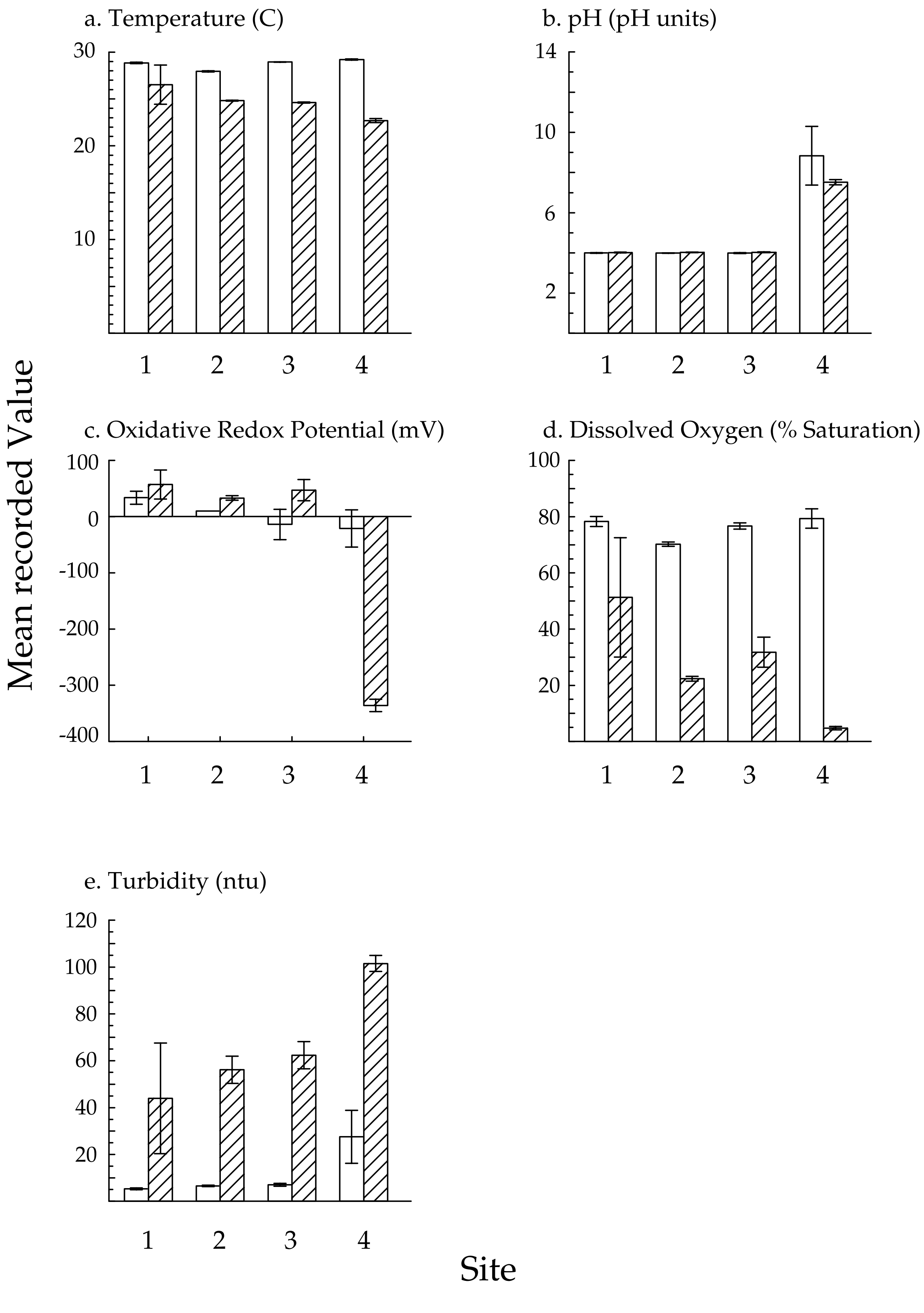

Figure 3. Mean and Standard error ($n = 2$) for water quality indicators measured at four sites at the surface (open bars) and bottom (hatched bars) of the subject water body.

PLATES

Plate 1. Photographs of the temporary outlet of the subject waterbody and the channel between the Big (E3) and Little (E2) lakes.

Plate 2. Photographs of Duchess Gully.

Plate 3. Photographs of various macrophytes on and around the subject water body.

Plate 4. Fauna collected during the site visit, January 2008.

a.

b.

c.

d.

e.

f.

Plate 1. Photographs of the temporary outlet of the subject waterbody and the channel between the Big (E3) and Little (E2) lakes. a) Culvert and upstream view to Big Lake; b) Culvert – Temporary weir structure showing in- and outflow; c) Pool below temporary weir structure; d) outlet downstream of culvert; e) main channel downstream of culvert (upstream of confluence with Duchess Gully; f) narrow channel between Big and Little lakes – arrow shows direction of flow out from Little Lake during the site visit. Plate 1f also shows dense growth of torpedo grass along shore.

a.

b.

c.

Plate 2. Photographs of Duchess Gully a) Confluence of Duchess Gully with the outlet of the outlet of the subject waterbody; b) Duchess Gully looking upstream from rainbow Beach; c) Duchess Gully looking downstream across Rainbow Beach towards its opening to the sea.

a.

b.

c.

d.

e.

Plate 3. Photographs of various macrophytes on and around the subject water body. a) Cape waterlily (*Nymphaea caerulea*, syn: *N. capensis*) and unidentified emergent plant; b) Cape waterlily and Florida torpedo grass (*Panicum repens*); c) Cumbungi (field identified as *Typha orientalis*); d) Torpedo grass with jointed twigrush (*Baumea articulata*) in foreground; and e) Water primrose (*Ludwigia peploides*).

a.

b.

c.

d.

Plate 4. Fauna collected during the site visit, January 2008. a) Sea mullet (*Mugil cephalus*); b) Freshwater mullet (*Myxus petardi*); c) Juvenile snake-necked turtle (*Chelodina longicolis*); d) Palaemonid shrimp (*Macrobrachium* sp.)

APPENDICES

Appendix 1. Water quality data collected in situ by depth and time (Source: Coffey 2008).

Appendix 2. Results of analyses of water samples collected from subject waterbody in 2005/6 and 2007 (Source: Coffey 2008).

Appendix 1. Water quality data collected *in situ* by depth and time (Source: Coffey 2008). Data compared to ANZECC (2000) guidelines for protection of aquatic ecosystems in frehwatewr lakes and reservoirs.

a. Temperature (C) (no ANZECC Guideline)

Depth	Date											Count	Mean	SE	95%CL	LCL	UCL
	Chandler Data set						Coffey data set										
	29/09/2005	13/10/2005	25/10/2005	17/11/2005	16/12/2005	17/02/2006	21/09/2007	31/10/2007	12/11/2007	27/11/2007	11/12/2007						
0	22.0	23.4	25.6	22.3	26.6		19.2	27.3	25.2	26.0	26.4	10	24.16	0.83	1.87	22.28	26.03
0.5	21.5	23.4	25.5	22.3	26.6	24.7	19.0	27.0	25.0	26.0	26.4	11	24.01	0.80	1.79	22.23	25.80
1	21.2	23.4	25.5	22.3	26.5	24.7	19.0	26.8	20.5	25.9	26.4	11	23.44	0.86	1.92	21.53	25.36
1.5	19.9	23.4	25.2	22.3	26.4	24.7	18.8	24.6	19.5	24.3	26.4	11	22.71	0.83	1.84	20.87	24.55
2	18.8	23.2	21.3	22.3	24.5	24.7	18.6	23.5	18.7	22.5	24.9	11	21.53	0.70	1.57	19.96	23.10
2.5	17.5	19.7	20.0	22.3	23.2	24.6	18.3	22.0	18.5	19.9	21.8	11	20.00	0.52	1.16	18.84	21.16
3							17.9	19.7	18.2	18.5	19.6	5	18.78	0.37	1.02	17.76	19.80
3.5							17.1	19.7	18.1	18.4		4	18.33	0.54	1.71	16.62	20.03
Statistics:																	
Count	6	6	6	6	6	5	8	8	8	8	7						
Mean	20.15	22.75	23.85	22.30	25.63	24.68	18.49	23.83	20.46	22.69	24.56						
SE	0.45	0.39	0.65	0.00	0.37	0.01	0.18	0.81	0.77	0.87	0.71						
95%CL	1.16	0.99	1.67	0.00	0.96	0.03	0.43	1.92	1.81	2.05	1.75						
LCL	18.99	21.76	22.18	22.30	24.68	24.65	18.06	21.91	18.65	20.64	22.81						
UCL	21.31	23.74	25.52	22.30	26.59	24.71	18.92	25.74	22.27	24.73	26.30						

b. pH (ANZECC: 6.5 to 8.0)

Depth	Date											Count	Mean	SE	95%CL	LCL	UCL
	Chandler Data set						Coffey data set										
	29/09/2005	13/10/2005	25/10/2005	17/11/2005	16/12/2005	17/02/2006	21/09/2007	31/10/2007	12/11/2007	27/11/2007	11/12/2007						
0	6.83	7.00	7.09	7.18	7.28		8.30	8.03	7.00	7.70	6.90	10	7.33	0.16	0.36	6.97	7.69
0.5	6.80	7.01	7.10	7.16	7.26	6.96	6.80	7.56	6.70	7.20	7.30	11	7.09	0.08	0.18	6.91	7.27
1	6.78	7.00	7.08	7.24	7.20	7.07	7.10	7.30	**6.50**	7.10	6.80	11	7.01	0.07	0.17	6.84	7.18
1.5	6.60	6.99	7.07	7.34	7.05	6.91	6.80	7.16	**6.30**	6.70	6.80	11	6.88	0.09	0.20	6.68	7.08
2	**6.44**	6.94	**6.50**	7.46	6.64	7.40	7.00	6.88	**6.30**	**6.30**	**6.10**	11	6.66	0.12	0.28	6.38	6.93
2.5	**6.34**	**6.40**	**6.49**	7.72	6.63	7.01	6.80	6.80	**6.30**	**6.30**	6.60	11	6.64	0.13	0.29	6.35	6.92
3							6.60	6.54	**6.30**	6.60	6.70	5	6.55	0.07	0.19	6.36	6.73
3.5							**6.40**	6.60	**6.30**	6.60		4	**6.48**	0.08	0.24	**6.24**	6.71
Statistics:																	
Count	6	6	6	6	6	5	8	8	8	8	7						
Mean	6.63	6.89	6.89	7.35	7.01	7.07	6.98	7.11	**6.46**	6.81	6.74						
SE	0.05	0.06	0.08	0.05	0.08	0.05	0.15	0.13	0.07	0.13	0.09						
95%CL	0.14	0.16	0.20	0.14	0.20	0.14	0.35	0.31	0.16	0.30	0.23						
LCL	**6.49**	6.73	6.69	7.21	6.81	6.93	6.62	6.80	**6.30**	6.52	6.52						
UCL	6.77	7.05	7.09	7.49	7.21	7.21	7.33	7.42	6.62	7.11	6.97						

continued…

Appendix 1, continued

c. EC (mS/cm) (ANZECC: 0.02 to 0.03)

Depth	Date											Count	Mean	SE	95%CL	LCL	UCL
	Chandler Data set						Coffey data set										
	29/09/2005	13/10/2005	25/10/2005	17/11/2005	16/12/2005	17/02/2006	21/09/2007	31/10/2007	12/11/2007	27/11/2007	11/12/2007						
0	**0.165**	**0.169**	**0.203**	**0.242**	**0.270**		**0.180**	**0.249**	**0.136**	**0.162**	**0.180**	10	**0.196**	0.014	0.031	**0.164**	**0.227**
0.5	**0.164**	**0.169**	**0.199**	**0.242**	**0.269**	**0.221**	**0.181**	**0.248**	**0.137**	**0.162**	**0.178**	11	**0.195**	0.013	0.029	**0.166**	**0.224**
1	**0.165**	**0.169**	**0.199**	**0.242**	**0.270**	**0.216**	**0.180**	**0.246**	**0.117**	**0.162**	**0.180**	11	**0.193**	0.014	0.031	**0.162**	**0.224**
1.5	**0.165**	**0.169**	**0.201**	**0.242**	**0.270**	**0.221**	**0.181**	**0.238**	**0.112**	**0.160**	**0.180**	11	**0.192**	0.014	0.031	**0.160**	**0.223**
2	**0.165**	**0.169**	**0.218**	**0.242**	**0.266**	**0.217**	**0.179**	**0.234**	**0.115**	**0.147**	**0.162**	11	**0.190**	0.014	0.032	**0.158**	**0.222**
2.5	**0.165**	**0.169**	**0.200**	**0.242**	**0.265**	**0.219**	**0.179**	**0.222**	**0.118**	**0.130**	**0.169**	11	**0.186**	0.014	0.031	**0.154**	**0.217**
3							**0.178**	**0.208**	**0.116**	**0.150**	**0.163**	5	**0.163**	0.015	0.042	**0.121**	**0.205**
3.5							**0.181**	**0.211**	**0.119**	**0.146**		4	**0.164**	0.020	0.064	**0.100**	**0.228**
Statistics:																	
Count	6	6	6	6	6	5	8	8	8	8	7						
Mean	**0.165**	**0.169**	**0.203**	**0.242**	**0.268**	**0.219**	**0.180**	**0.232**	**0.121**	**0.152**	**0.173**						
SE	0.000	0.000	0.002	0.000	0.001	0.001	0.000	0.004	0.002	0.003	0.002						
95%CL	0.000	0.000	0.005	0.000	0.001	0.002	0.001	0.010	0.006	0.007	0.005						
LCL	**0.165**	**0.169**	**0.198**	**0.242**	**0.267**	**0.217**	**0.179**	**0.222**	**0.115**	**0.145**	**0.168**						
UCL	**0.165**	**0.169**	**0.208**	**0.242**	**0.270**	**0.220**	**0.181**	**0.242**	**0.127**	**0.159**	**0.178**						

d. ORP (mV)(no ANZECC Guideline)

Depth	Date											Count	Mean	SE	95%CL	LCL	UCL
	Chandler Data set						Coffey data set										
	29/09/2005	13/10/2005	25/10/2005	17/11/2005	16/12/2005	17/02/2006	21/09/2007	31/10/2007	12/11/2007	27/11/2007	11/12/2007						
0	200.0	185.5	141.3	106.1	89.9		111.0	201.7	144.7	123.0	122.2	10	148.4	12.0	27.1	121.3	175.5
0.5	211.7	186.0	141.8	108.1	89.3	53.0	113.0	197.0	138.2	114.7	129.6	11	148.9	11.8	26.3	122.6	175.2
1	222.0	185.1	141.0	111.1	90.1	82.1	109.7	196.2	145.8	114.0	117.5	11	149.2	12.7	28.2	120.9	177.4
1.5	261.2	186.8	139.6	114.0	95.2	50.9	112.2	198.1	149.6	125.6	116.8	11	156.0	15.2	33.8	122.2	189.8
2	287.1	186.5	143.7	116.4	97.7	76.2	113.5	197.5	147.9	138.9	141.1	11	163.6	16.3	36.3	127.3	200.0
2.5	310.6	197.2	139.8	121.1	72.4	74.3	113.0	198.4	146.8	113.9	-35.0	11	145.1	27.8	61.9	83.2	207.0
3							123.8	88.0	123.6	81.0	-273.9	5	28.5	76.1	211.3	-182.8	239.8
3.5							96.0	62.0	121.3	21.0		4	75.1	21.7	69.2	5.9	144.3
Statistics:																	
Count	6	6	6	6	6	5	8	8	8	8	7						
Mean	248.8	187.9	141.2	112.8	89.1	67.3	111.5	167.4	139.7	104.0	45.5						
SE	11.5	1.2	0.4	1.4	2.3	3.7	2.0	14.8	2.9	9.6	39.6						
95%CL	29.6	3.1	1.0	3.7	5.9	10.3	4.6	35.1	6.8	22.8	96.8						
LCL	219.2	184.8	140.2	109.1	83.2	57.0	106.9	132.3	132.9	81.2	-51.3						
UCL	278.3	190.9	142.2	116.5	95.0	77.6	116.2	202.4	146.6	126.8	142.3						

continued…

Appendix 1, continued

e. Dissolved Oxygen (% saturation) (ANZECC: 80 - 110%)

Depth	Date											Count	Mean	SE	95%CL	LCL	UCL
	Chandler Data set						Coffey data set										
	29/09/2005	13/10/2005	25/10/2005	17/11/2005	16/12/2005	17/02/2006	21/09/2007	31/10/2007	12/11/2007	27/11/2007	11/12/2007						
0	**120.1**	**128.0**	**128.5**	**121.3**	**124.2**		**140.0**	**113.0**	**72.0**	88.0	**74.0**	10	109.4	7.9	17.9	91.5	**127.4**
0.5	**116.7**	**129.5**	**128.3**	**122.3**	**122.4**	**74.4**	**140.0**	109.0	**70.0**	81.0	**75.0**	11	108.0	7.9	17.5	90.5	**125.5**
1	**117.7**	**127.5**	**128.2**	**121.2**	**120.1**	81.2	**115.0**	97.0	**54.0**	**79.0**	**72.0**	11	101.3	8.2	18.2	83.1	**119.5**
1.5	**104.0**	**129.1**	**127.4**	**120.8**	**116.9**	**70.6**	**140.0**	83.0	**58.0**	**43.0**	**67.0**	11	96.9	10.6	23.7	**73.2**	**120.6**
2	88.8	**127.2**	88.4	**120.6**	**43.6**	**72.1**	103.0	**71.0**	**60.0**	**11.0**	**8.0**	11	**75.3**	13.0	28.9	**46.5**	104.2
2.5	**63.5**	**78.4**	**74.5**	**122.2**	**17.9**	**45.5**	**110.0**	**53.0**	**59.0**	**8.0**	**7.0**	11	**64.0**	11.8	26.4	**37.6**	90.4
3							100.0	**15.0**	**53.0**	**5.0**	**6.0**	5	**35.8**	18.3	50.8	**-15.0**	86.6
3.5							**46.0**	**15.0**	**48.0**	**5.0**		4	**28.5**	10.9	34.6	**-6.1**	**63.1**
Statistics:																	
Count	6	6	6	6	6	5	8	8	8	8	7						
Mean	101.8	**120.0**	**112.6**	**121.4**	90.9	**68.8**	**111.8**	**69.5**	**59.3**	**40.0**	**44.1**						
SE	5.7	5.3	6.3	0.2	12.2	3.5	8.1	10.1	2.1	9.7	9.0						
95%CL	14.7	13.5	16.3	0.5	31.4	9.8	19.2	23.8	5.0	22.9	22.0						
LCL	87.1	106.4	96.3	**120.9**	**59.4**	**59.0**	92.5	**45.7**	**54.2**	**17.1**	**22.1**						
UCL	**116.5**	**133.5**	**128.8**	**121.9**	**122.3**	**78.5**	131.0	93.3	**64.3**	**62.9**	**66.2**						

Appendix 2. Resutls of analyses of water samples collected from subject waterbody in 2005/6 and 2007 (Source: Coffey 2008).

a. Coffey Data

Date of sampling		Turbidity (ntu)	TN (mg/L)	TP (mg/L)	Chl_a (mg/L)
	ANZECC:	1-20	0.35	0.01	5
3/08/2007		15.60	**0.53**	**0.025**	2
22/08/2007		**30.80**	**0.64**	**0.025**	2
7/09/2007		17.50	**0.67**	**0.025**	4
21/09/2007		12.30	**0.55**	**0.03**	**9**
31/10/2007		7.95	**0.47**	**0.02**	**5**
12/11/2007		**28.10**	**0.63**	**0.03**	2
27/11/2007		11.70	**0.79**	**0.02**	2
10/12/2007		8.30	**0.62**	**0.04**	**10**
Summary statistics:					
count		8	8	8	8
mean		16.53	**0.61**	**0.03**	4.50
SE		3.05	0.03	0.00	1.16
95%CL		7.22	0.08	0.01	2.76
LCL		9.31	**0.53**	**0.02**	1.74
UCL		**23.75**	**0.69**	**0.03**	**7.26**

b. Chandler Data

Date of sampling		Turbidity (ntu)	TN (mg/L)	TP (mg/L)	Chl_a (mg/L)
	ANZECC:	-	0.35	0.01	-
29/09/2005		nd	**0.44**	**0.02**	nd
13/10/2005		nd	**0.47**	**0.02**	nd
25/10/2005		nd	**0.56**	**0.03**	nd
17/11/2005		nd	**0.46**	**0.02**	nd
1/12/2005		nd	**0.41**	**0.02**	nd
16/12/2005		nd	**0.43**	**0.01**	nd
17/02/2006?		nd	**0.62**	**0.02**	nd
Summary statistics:					
count			7	7	
mean			**0.48**	**0.02**	
SE			0.03	0.00	
95%CL			0.07	0.01	
LCL			**0.41**	**0.01**	
UCL			**0.56**	**0.03**	

[shaded] = reported as "<0.05"

bold ≥ANZECC