



Corangamite Catchment Management Authority

Reedy Lake Environmental Flow and Monitoring Restoration Project - Integrated Monitoring Report

September 2017

Executive summary

Background

Reedy Lake is a large freshwater wetland of approximately 550 ha which forms part of the Lake Connewarre Complex and the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site (DSE, 2003).

The *Seasonal Watering Proposal for the Lower Barwon Wetlands 2017 -18* defines a four year wetting drying regime for Reedy Lake which includes:

- a low-partial dry summer regime in one year
- low water levels in the following two years and
- a full water level year.

All four years include a full water level in winter.

The *Reedy Lake Integrated Monitoring Program* is a biophysical monitoring program to assess the outcomes of the implementation of the Reedy Lake wetting and drying regime. A key focus was monitoring changes in water and sediment quality during the drying regime to assess and manage potential risks from acid sulphate soil activation and impacts from contaminants. The low partial drying of Reedy Lake maintained water levels at >0.0 m AHD.

Outcomes of the *Reedy Lake Integrated Monitoring Program* include:

Surface water, sediment and groundwater

- Monitoring for surface water, sediment and groundwater indicated that there were marginal, if any, change to the physicochemical conditions sediment, surface water and groundwater of Reedy Lake during the low-partial drying regime.
- The low-partial drying, maintained at >0m did not result in a short-term adverse impact. Coastal Acid Sulphate Soils was not generated and there was no increase in metal concentrations which are comparable to ANZECC water quality guidelines.
- Subsequent drying events are unlikely to generate acid events or liberate metals from sediments, which could impact the ecological value of Reedy Lake.

Fish

- European Carp were the numerically dominant fish species (particularly in deeper areas), followed by the native Common Galaxias and Small-mouthed Hardyhead.
- Maintenance of water levels at 0.0 m AHD or above is unlikely to have a major impact on native fish species. All native fish species tolerate a range of salinities, and any reduction in native fish populations in Reedy Lake as a result of drying would be replenished through recruitment from the Barwon River as the lake fills.
- Maintaining water levels at 0.0 m would limit adverse water quality conditions and reduce impacts of potential threats to native fish communities from increased competition for resources and predation (e.g. by carp) and adverse water quality (pH, dissolved oxygen).
- Surveillance and monitoring of carp movement during the drying regime identified opportunities for eradication of carp when water levels are low and carp congregate in the outlet channel. Concentration of individuals and physical removal could be implemented at the outlet channel culverts.

Birds

- The monitoring in January 2017 encountered very dry conditions at the lake. Consequently, a lower number of waterbirds were seen and no shorebirds/waders were seen other than Masked Lapwings (17% of the wetland-associated species and 43% of the non-wetland-associated species were recorded).
- The general absence of shorebirds and waterbirds indicates a short-term response by the birds to the lowered water level, and should not be considered a long-term response to the onset of the altered watering regime.
- A review of previous data identified it is difficult to determine whether changes in bird numbers at Reedy Lake are influenced by changing water levels at the lake or by changes in habitat availability and/or quality elsewhere. The value and usefulness of historical data for establishing baseline data are limited by inconsistent data-collection methods over previous years or projects.

Amphibians

Frog monitoring has identified the five species identified during surveys have some differences in habitat preferences. Frog populations will respond to the wetting and drying regime in accordance with habitat availability as influenced by water levels.

- The eastern froglet (*Crinia signifera*) and spotted grass frog (*Limnodynastes tasmaniensis*) appear to favour habitats around the margins of the lake responding to higher water levels.
- The southern brown tree frog (*Litoria ewingi*) appears to favour taller vegetated habitats within the deeper and more permanent parts of the lake where water levels are more persistent.
- The nationally listed growling grass frog (*Litoria raniformis*) and eastern banjo frog (*Limnodynastes dumerili*) are not present in large numbers around the lake. Both species favour deeper and more permanent parts of the lake.

Vegetation

- Vegetation monitoring provided a baseline of vegetation distribution and abundance. The program identified relatively minor changes in most species and their distribution and those of plant functional groups compared to previous monitoring (2013/14).
- While the *Phragmites* and *Typha* monitoring transects established in 2013/2014 were not re-measured as part of the current project some of the quadrat data indicate further spread of reeds and rushes from consistently high water levels.
- Vegetation monitoring results indicate that consistently elevated water levels in Reedy Lake have continued to influence vegetation quality, function and extent, favouring deeper water species (native and exotic), disadvantaging other native species that respond to water fluctuations and encouraging the spread of weeds.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 9 and the assumptions and qualifications contained throughout the Report.

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1. Acknowledgements

GHD thanks Craig Morley, David Tytherleigh and Peter Phillips of the Geelong Field Naturalist Club, for generosity with their time and information during the bird monitoring event at Reedy Lake in January 2017. Craig was particularly helpful with facilitating access to historical reports and bird data.

2. Introduction

2.1 Background

Reedy Lake is part of the Lake Connewarre Complex includes Lake Connewarre, Hospital and Salt Swamps, and associated sections of the Lower Barwon River. The Complex forms part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site (DSE, 2003). Reedy Lake is a State Game Reserve of approximately 550 hectares (ha) and is located to the north-east of the lower Barwon River and is connected to Lake Connewarre on the southern side.

Reedy Lake is best described as a large freshwater wetland dominated by tall reed communities of Common Reed (*Phragmites australis*) and Cumbungi (*Typha orientalis*). The wetland is fringed by low saline herbfields, brackish shrubland, grassland and sedgeland with predominantly cleared rural-residential land at higher elevation on the west, north and eastern sides (Billows and Gwyther 2001, Llyod 2012).

The Lake has a small local catchment of 27 km but is flooded almost entirely from the Barwon River. The Lake supports a range of activities including duck hunting, commercial eel fishing, recreational fishing, passive recreation (especially bird watching) and scientific research. When sufficient emergent vegetation is present, several thousand Straw-necked Ibis (*Threskiornis spinicollis*) and hundreds of White Ibis (*Threskiornis molucca*) breed in Reedy Lake (DSE, 2003).

2.2 History of water regime and management

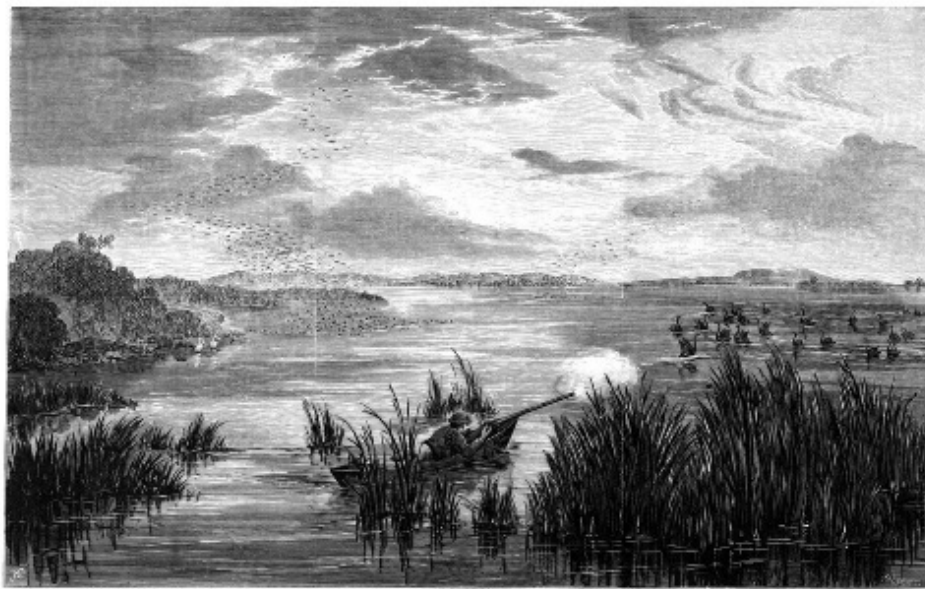
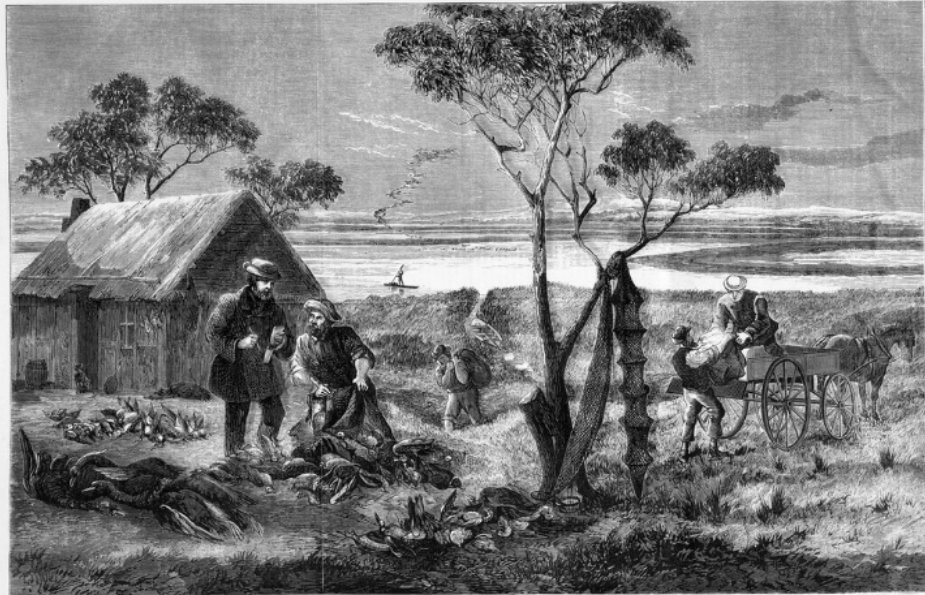
Reedy Lake is managed by Parks Victoria with Corangamite Catchment Management Authority (CCMA) managing the Barwon River Environmental Water Entitlement which was established in 2011). Consistent with the objectives of the *Water Act 1989* and those of the Ramsar Convention, the objective of environmental water management for the Lower Barwon Wetlands is to maintain the diversity and populations of waterbirds, fish and other fauna dependant on the Lake Connewarre Complex and its plant communities (CCMA, 2012).

The environmental water requirements for Reedy Lake were established by Lloyd *et al* (2012). The proposed water regime is established around a four year cycle including one year in for as a wet or dry year and an interquartile year (two years in four). This includes the lake being at its highest in winter/spring (0.8 m AHD), in a drying period lowering the water level to 0.3 m AHD by late summer, and refilling in April/May, in response to autumn breaks (Lloyd *et al*. 2012).

Until the early 1980's the hydrology of Reedy Lake was manipulated for mainly grazing and irrigation purposes (Lloyd *et al*. 2012). Since the termination of grazing and irrigation licences, hydrology has been managed for both conservation and recreational purposes (e.g. duck hunting) and more recently for conservation. In recent history, water levels in Reedy Lake have been regulated through the Barwon River breakwater, constructed in 1970 to maintain a constant water level above 0.7 m AHD. This has resulted in a change to inflows into the Reedy Lake system from predominantly saline to fresh. The modifications to Reedy Lake's hydrological regime contributed to an increase in the depth and permanence of water and reduced salinity, making conditions more favourable for Bullrush and Common Reed (Dahlhaus and Currell, 2013). Other environmental concerns associated with the change in hydrological change to Reedy Lake include fluctuations in European Carp (*Cyprinus carpio*) populations, and the occurrence of weeds around the margins due to grazing by rabbits (DSE, 2003).

Since modification to the morphology and natural hydrology of Reedy Lake, freshwater has been retained. The exception has been a few events that have resulted in the drying of the lake.

In the summer of 2005 to 2006 the State government initiated an artificial drying event, primarily to manage high levels of exotic Carp and protect the presence of ecological vegetation communities. Since 2006 the *status quo* of water retention in Reedy Lake has resulted in a stabilised environment between the surface water, sediment and groundwater, which has changed the ecological character and caused the proliferation of invasive reed species *Phragmites* and *Typha*. Reedy Lake's ecological values and diversity have been in decline due to a constant and static full water level over the past 10 years (CCMA, March 2017).



2.3 Scope of this project

GHD has recently completed investigations for CCMA in 2014 and 2015 to develop a comprehensive understanding of the condition of the surface water, groundwater and sediment in Reedy Lake. The *Reedy Lake Contaminants Measurement Assessment (GHD 2015)* confirmed that the risks to the ecological values of Reedy Lake largely relate to sediment where sediment metal concentrations have accumulated over time and the presence of coastal acid sulphate soils (CASS). The investigation identified there was a risk during a drying event that oxidation of CASS could occur resulting in an acid event and mobilisation of metals from sediments into the water column. This risk to the ecological values in the Lake was considered to be higher in the deeper sections of Reedy Lake, predominantly at <0.0 m AHD.

The GHD study was used to inform the *Seasonal Watering Proposal for the Lower Barwon Wetlands 2017 -18*, published by CCMA in March 2017 (CCMA, 2017). The Proposal focuses on implementing an environmental watering regime for Reedy Lake that will maintain and improve the ecological character of the wetland. Environmental watering, and the implementation of drying regimes have been identified as the single most important management activity to protect the ecology of Reedy Lake and the Lower Barwon wetlands (CCMA, 2017).

The water regime approved for Reedy Lake involves a four year water cycle regime, as presented in Figure 1, which includes:

- a low-partial dry summer regime in one year,
- low water levels in the following two years and
- a full water level year.

All four years include a full water level in winter.

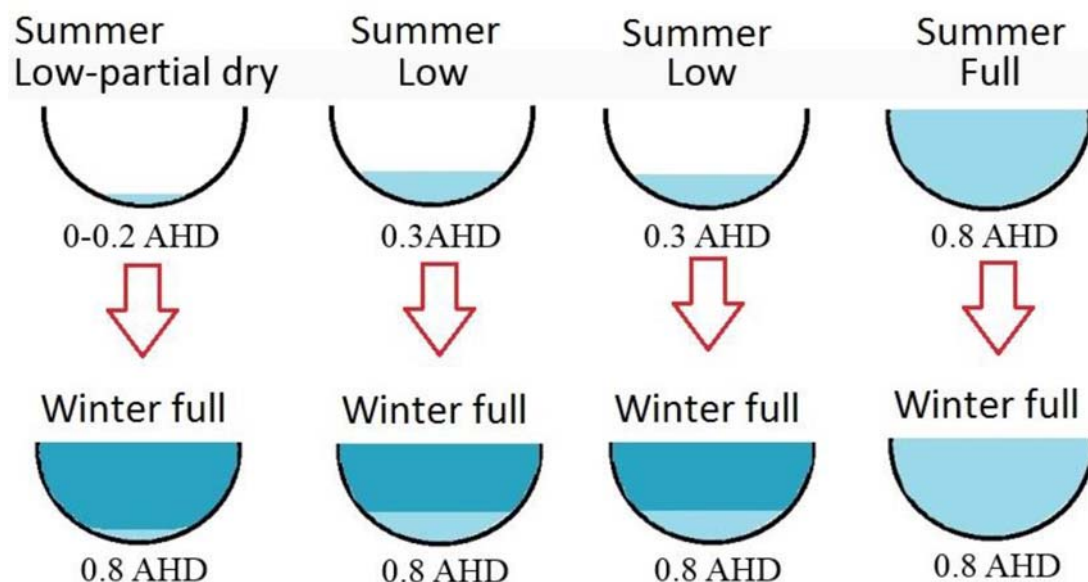


Figure 1 Reedy Lakes scientifically validated four-year watering regime (sourced from CCMA March 2017).

In November 2016, CCMA initiated the environmental flow recommendations by implementing the first low to partially dry summer regime. Water levels were reduced to 0.0 m AHD.

GHD was engaged to establish and undertake an environmental monitoring program for Reedy Lake, in association with management change to its water regime initiation and the first low partially dry summer regime of 2016-17. The approach for the monitoring is aimed at CCMA's objective to manage environmental risk associated with implementing the drying regime in the

2016-17 water year. The environmental monitoring will provide valuable data to understand ecosystem response in Reedy Lake as a consequence of the altered water regime and provide information to manage unforeseen impacts associated with potential changes in sediment and water chemistry.

2.4 Purpose of this report

The objective of the monitoring program is to assess the response of a range of ecological sediment and water quality parameters in Reedy Lake to the drying event in 2016-17.

This report presents the methods and findings of the integrated monitoring of Reedy Lake during the altered drying regime. The report discusses outcomes of the Reedy Lake monitoring of the drying event during the summer of 2016-2017:

- Surface water, groundwater, and sediment quality (Chapter 3)
- Fish (Chapter 4)
- Birds (Chapter 5)
- Amphibians (Chapter 6)
- Flora and fauna (Chapter 7)

Each chapter outlines the scope of works and existing background information. Survey approach and results are presented and discussed. A discussion of the results and recommendations for ongoing monitoring has also been provided in each chapter.

The results of the monitoring program will inform the Corangamite CMA's management of the Lake for the summer of 2017-18 and future years.

3. Surface water, sediment and groundwater monitoring

3.1 Objective

The objective of this component of the project was to assess the changes in the water, sediment and groundwater quality in Reedy Lake during 2016/2017 environmental watering regime, which involved decreasing water levels to >0.0 m AHD

3.2 Background

The *Reedy Lake Contaminants Measurement Assessment (GHD 2015)* provided an understanding of the baseline quality of the sediment, surface water and groundwater in Reedy Lake. The GHD (2015) report identified that a return to the more natural drying regime at Reedy Lake is not likely to pose significant long term risk to water and sediment quality if drying is maintained to a level of >0.0 m AHD. Coastal acid sulfate soil (CASS) is prevalent across the region and the study reported low pH and elevated metals across a number of locations in Reedy Lake. Based on the results, it was deemed that CASS present in Reedy Lake >0.0 m AHD has been previously oxidised through long term repeated wetting and drying of the sediments. The report concluded that risk of an altered water regime to Reedy Lake's ecosystem is more pronounced in the deeper zones (<0.0 m AHD) as the CASS have not been activated.

The GHD (2015) report compared results to the Australian and New Zealand Environment Conservation Council (ANZECC) Australian and New Zealand guidelines for fresh and marine water quality (ANZECC 2000). These guidelines provide a framework for conserving ambient water quality in our rivers, lakes, estuaries and marine waters and outline trigger values for a range of water quality indicators. The trigger values for water quality indicators are concentrations that can be used to assess the risk to an aquatic ecosystem; an increase measured above trigger values indicates there may be a risk to environmental values.

Trigger values outlined in ANZECC (2000) were used during the GHD (2015) assessment as the basis for assessing potential risk to Reedy Lake during drying. A number of water quality parameters were identified higher than ANZECC (2000) trigger values, which were more pronounced in the deeper sections of Reedy Lake.

3.3 Methods for Monitoring

Monitoring methods for this investigation are based the monitoring regime outlined in GHD (2015)

3.3.1 Water level

Changes in water level were assessed through data obtained from gauging station 233603A (Reedy Lake @ Connewarre). Water level data included 15-minute observations from 1 May 2016 through to 27 April 2017.

Changes in water levels in Reedy Lake are influenced by climate such as rainfall and air temperatures. Climate information from May 2016 through to April 2017 were obtained from the Bureau of Meteorology station 87184 located at the Breakwater near the Geelong Racecourse.

3.3.2 Ambient surface water quality

The *in situ* water quality monitoring occurred on 27 and 28 February 2017 in accordance with GHD's Surface Water Sampling Procedure (GHD 2015)). Water quality was monitored at seven sites across Reedy Lake (Table 1). These were the same sites assessed in previous monitoring of Reedy Lake during January 2014 which supports a comparison of changes over time due to differences in water level.

Table 1 Location of surface water monitoring sites in Reedy Lake

Site Code	Location	Eastings	Northings
WQ_Inlet ¹	Lower Barrage Inlet	273943	5767550
WQ1	North Reedy lake	275483	5769254
WQ2 ₁	East Reedy Lake	275335	5767311
WQ3	West Reedy Lake	273062	5769014
WQ4 ₁	South Reedy Lake	274014	5767906
WQM	Mid Reedy Lake (deepest region)	274515	5768295
WQ_Outlet ¹	Lower Barrage Outlet	275098	5767179

¹. These sites were also monitored for *in situ* water quality during April 2017.

WQ3 is an open stormwater drain that feeds into Reedy Lake and was included as an additional site to determine if such inputs contribute to changes in water quality. Due to the low water levels during the 2016/17 drying regime, WQ1 was dry and no *in situ* recordings were recorded at this site. At all other sites *in situ* surface water quality (<0.5 m depth) was recorded using a calibrated portable water quality meter and field test kits. Previous monitoring by GHD (2015) identified there was no stratification present in Reedy Lake during the warmer parts of the year and surface water recordings sufficient to assess *in situ* water quality.

Additional *in situ* water quality monitoring was also carried out for a select number of parameters on 4 April 2017 when the water level in Reedy Lake had increased to 0.27 m (see Table 1). This was done to assess changes in water quality as water levels increased. The stormwater site (WQ3) was not monitored on this occasion. In both February and April 2017, *in situ* water quality was monitored on either side of the inlet and outlet structures.

In situ parameters assessed were temperature (°C), dissolved oxygen (mg/L), percentage saturation of dissolved oxygen (%), pH (pH units), electrical conductivity (µS/cm), oxidation-reduction potential (mV), turbidity (NTU) and alkalinity (mg/L). Alkalinity was recorded using a Hach Alkalinity Test Kit (Model AL-TA) and turbidity with a Turbiquant 1100IR meter. All other parameters were recorded using a TPS Series 90FL Field Analyser. All water quality equipment was calibrated as per manufacturer's recommendations. To complement the *in situ* water quality monitoring, EC and DO data were also obtained at 15-minute intervals from 1 May 2016 through to 27th April 2017 from gauging station 233603A – Reedy Lake @ Connewarre (located within Reedy Lake).

On 28 January 2017, water samples were collected at site WQM from surface waters only (<0.5 m). The water samples were collected for laboratory analyses of alkalinity, major anions (sulfate, chloride), major cations (calcium, magnesium, sodium, potassium), ionic balance, dissolved metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury), total and dissolved organic carbon.

The major cations and anions were collected in 250 mL polyethylene bottles and stored on ice. The TOC and DOC samples were collected in 40 mL amber glass bottles and preserved with sulphuric acid. The DOC samples were filtered in the field using a Whatman GFC filter. The dissolved metals were collected in 60 mL polyethylene bottles and preserved with nitric acid. Samples for dissolved metals were field filtered using Waterra 45 micron inline filters. All water samples were analysed at the ALS NATA accredited laboratory in Springvale.

3.3.3 Ambient sediment quality

Sediment monitoring was undertaken in accordance with *EPA Publication IWRG701 Sampling and analysis of waters, wastewaters, soils and wastes* (2009). Sediment samples were collected from three sites on 28 February and 4 April 2017 (Table 2). The three sites (S1, S7 and S8) were selected as they were identified as having high metal concentrations and high acid sulfate generation potential and were likely to pose a risk following the low-partial dry summer regime (see GHD, 2015).

Table 2 Site locations of sediment monitoring in Reedy Lake

Site Codes	Eastings	Northings
S1 (Outlet)	275098	5767179
S7 (Inlet)	273943	5767550
S8	274014	5767906

At each site, sediment cores were collected with a polyvinyl chloride (PVC) corer that had a 5.5 cm diameter and 1.2 m length. The corer was pushed into the sediment to a vertical depth of at least 0.5 m below the substrate. The corer was thoroughly rinsed following the collection of each sample and allowed to dry prior to the collection of samples from other sites.

Each sample was transferred into clean plastic bags and stored on ice until they were frozen at the end of each monitoring day. The total metals/metalloids samples were retained in 250 mL glass jars.

Sediment quality was analysed by ALS, a NATA accredited laboratory at all sites for major cations (sodium, potassium, calcium, magnesium), major anions (chloride), sulphate, alkalinity and dissolved metals/metalloids (aluminium, antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver and zinc).

3.3.4 Groundwater quality

Groundwater monitoring was undertaken in accordance with *EPA Publication 669 Groundwater Sampling Guidelines* (2000). During the April 2017 monitoring, the groundwater quality was assessed in three bores around the perimeter of the lake; UB_FG1, UB_WH1 and UB_CS2 (Table 3). It was originally proposed to monitor a fourth bore but due to excessive reed growth at the south-western region of the lake the bore could not be located.

Table 3 Groundwater Bore Locations

Bore ID	Location	Easting	Northing	Measured Bore Depth (2017)
UB_CS2	West of Lake	272506	5768401	6.71
UB_FG1	East of Lake	275810	5767736	11.35
UB-WH1	North of Lake	275383	5769482	8.59

Prior to purging and sampling of groundwater, the standing water level (SWL) was measured at each monitoring bore using a dip meter. SWLs were measured from the top of the PVC casing, which was generally a raised standpipe.

Groundwater monitoring included the *in situ* assessment of

- pH
- electrical conductivity ($\mu\text{S}/\text{cm}$)

- dissolved oxygen (mg/L)
- oxidation-reduction potential (mV) and
- temperature (°C)

All parameters were recorded using a Hanna Multimeter Water Quality Meter (calibrated daily as per manufacturer's recommendations). The parameters were periodically measured until they had stabilised or close to stabilisation, indicating the groundwater was representative of the aquifer.

Once *in situ* parameters had stabilised, groundwater samples were collected using a bailer. Prior to purging and sampling of each groundwater monitoring bore, the standing water level (SWL) was measured at each monitoring bore using a dip meter. SWLs were measured from the top of the PVC casing, which was generally a raised standpipe.

Water samples were collected for the analyses of:

- electrical conductivity ($\mu\text{S}/\text{cm}$)
- total dissolved solids (TDS)
- alkalinity (hydroxide as CaCO_3 , carbonate as CaCO_3 , bicarbonate as CaCO_3)
- major cations (sodium, potassium, calcium, magnesium)
- major anions (chloride), sulphate as SO_4)
- total organic carbon (TOC)
- dissolved metals/metalloids (arsenic, cadmium, chromium, copper, lead, nickel, and zinc)

The major cations and anions samples were collected in 250 mL polyethylene bottles and stored on ice. The dissolved and total metals/metalloids were collected in 60 mL polyethylene bottles and preserved with nitric acid. Samples for dissolved metals were field filtered using Waterra 45 micron inline filters before being placed in a container with appropriate preservation. All water samples were analysed at the ALS NATA accredited laboratory in Springvale.

3.4 Results

The results collected in 2016/17 during the low-partial dry summer regime are presented in the following sections, and are compared against the GHD (2015) baseline assessment and ANZECC (2000) water quality guideline criteria. Comparison of results with ANZECC (2000) provides an indication of the impact from full drying to some of the physical, biological and chemical characteristics of sediment and water quality that would otherwise be required to support the health of environmental values in Reedy Lake. The ANZECC (2000) trigger values are used as a guideline only to indicate changes in the quality of Reedy Lake against nationally applied trigger values. The guideline trigger values applied for comparison with results collected in 2016/2017 are relevant for 95% species protection in either marine and fresh water.

3.4.1 Reedy Lake water level

Changes in the water level of Reedy Lake (Gauge 233603A Reedy Lake @ Connewarre) are included in Figure 2. On 1 May 2016 water level was at 0.63 m before gradually rising to 0.94 m on 9 September 2016. There were abrupt spikes in water level during September, October and November 2016 that may be related to increased rainfall and over topping of the levee from the Barwon River.

Water level reached a maximum of 2.13 m in mid-November before decreasing to around 0.68 m. Water level continued to decrease during the 2016/17 drying period and reached a minimum of 0.10 m in late March 2017. From late March into April water level increased and reached 0.82 m towards the end of April 2017.

The abrupt downward spikes below 0.0 m were a consequence of errors in the telemetry meter, which were rectified quickly by a third party.

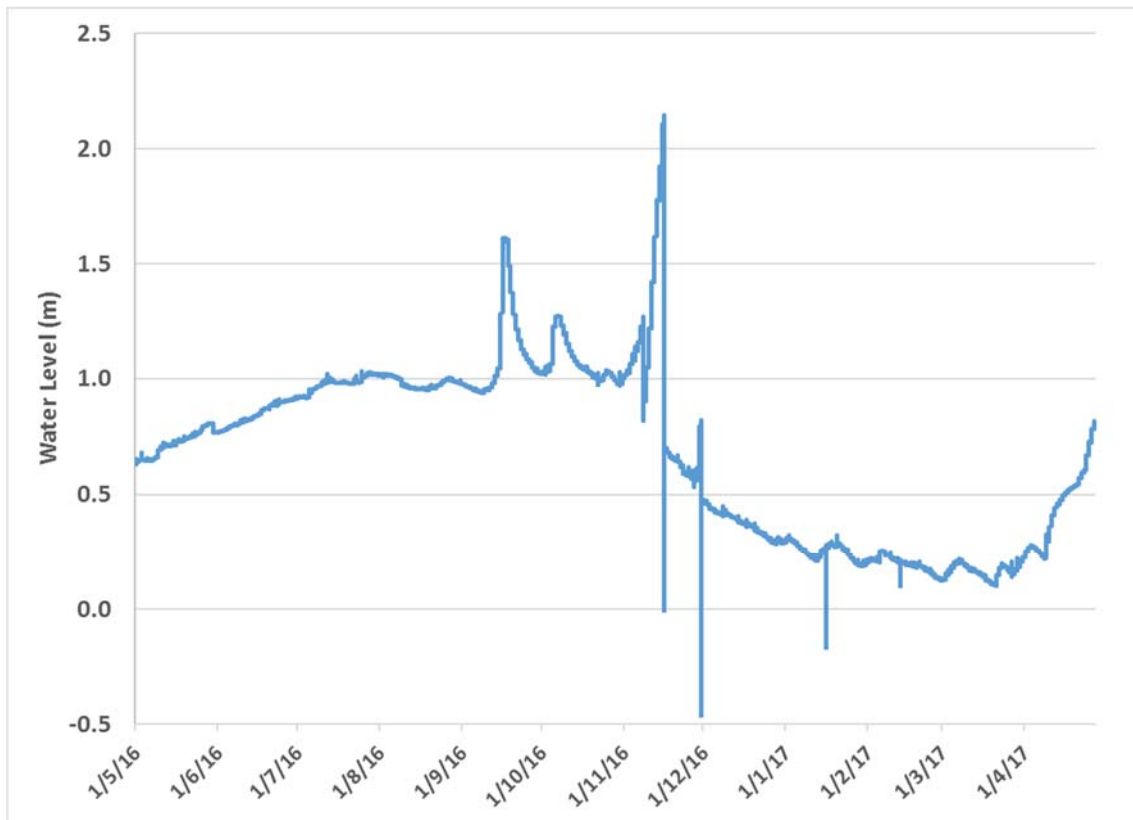


Figure 2 Water level changes in Reedy Lake from the 1st May 2016 through to the 27th April 2017 as recorded at gauge 233603A Reedy Lake @ Connewarre

Climate information for the greater Geelong area are included in Figure 3. Air temperatures followed a predictable pattern and was higher during the spring/summer period than for autumn/winter. Rainfall fluctuated during winter/spring (June to September) and was relatively low from November to January before increasing in February and March. There was a significant rainfall event during April when over 151 mm was recorded in the Geelong region.

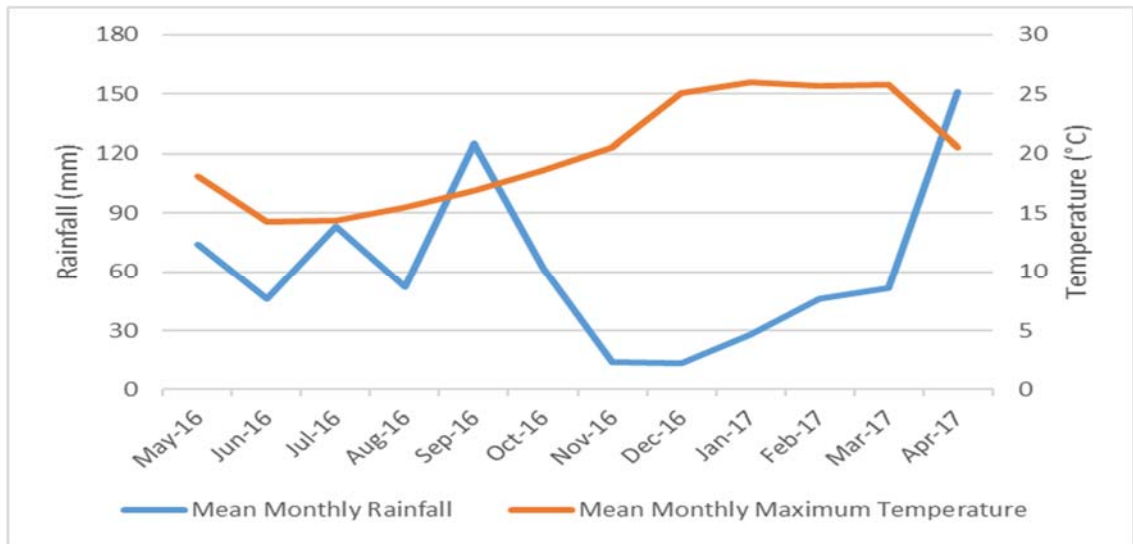


Figure 3 Mean monthly rainfall and mean monthly maximum air temperature as recorded at Bureau of Meteorology station 87184 located at the Breakwater near the Geelong Racecourse

3.4.2 Ambient surface water quality

In situ water quality results are presented for January 2014 (baseline) and February 2017 at the seven Reedy Lake sites (Table 4). In both years, water temperature aligned with the ANZECC (2000) guideline trigger value. Although there was some variation amongst sites and years more likely due to differences in the time of monitoring and air temperatures rather than changes in water levels.

With the exception of WQ1, WQM and WQ_Outlet there was low dissolved oxygen (DO) during 2014 with the majority of sites below the ANZECC (2000) guideline. During 2017 there was noticeably higher DO at most sites although at WQ2 and WQ_Outlet levels were low at <16% saturation which is expected when implementing a drying regime. All sites were not within the ANZECC (2000) guideline and were measured with either low or high DO. In both 2014 and 2017, electrical conductivity (EC) at all sites were higher than ANZECC (2000) guideline. EC was significantly higher at all sites during 2017 compared with 2014 except for the stormwater drain (WQ3) where it was considerably lower.

Measured pH was higher the ANZECC (2000) guideline of pH 8.0 units at the majority of sites in both years although there was some evidence of higher pH during 2017 compared to 2014. Turbidity has also higher the ANZECC (2000) guideline of 20 NTU at most sites in both years but was generally higher in 2017. Oxidation-reduction potential (ORP) was positive and ranged from 58 to 120 mV at all Reedy Lake sites during 2014 but was -24 in the stormwater drain (WQ3). During 2017 all sites were negative and ranged from -110.9 to -38.9 mV. In general, alkalinity was higher during 2014 compared to 2017 at the majority of sites.

Table 4 *In situ* water quality results from Reedy Lake.

	Temperature (°C)		Dissolved Oxygen (mg/L)		Dissolved Oxygen (%)		Electrical Conductivity (µS/cm)		pH (Units)		Turbidity (NTU)		Oxidation Reduction Potential (mV)		Alkalinity (mg/L)	
	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17	Jan-14	Feb-17
WQ_Inlet	26.9	27.0	4.0	16.1	50.7	218.7	1,907	22,131	7.8	9.5	7	147	95	-39	220	240
WQ1	30.0	Dry	7.2	Dry	96.7	Dry	6,190	Dry	9.2	Dry	38	Dry	58	Dry	360	Dry
WQ2	23.3	17.7	2.2	1.4	25.7	15.7	5,240	16,589	7.9	8.3	22	55	94	-54	500	260
WQ3	21.2	30.3	1.3	11.1	14.7	147.8	8,130	270	7.6	9.2	60	8	-24	-90	560	55
WQ4	22.9	23.4	3.8	15.5	44.1	196.7	1,651	21,009	8.1	9.4	33	141	82	-59	180	240
WQM	25.7	29.0	8.0	16.8	99.4	237.0	3,160	23,066	9.1	9.8	13	147	120	-59	280	240
WQ_Outlet	27.8	20.4	7.1	1.1	91.3	12.7	4,540	10,741	8.8	8.0	26	35	108	-111	380	240
ANZECC (2000)	15 - 35		NA		90 - 110		20 - 30		6.5 – 8.0		1 - 20		NA		NA	

Note: Values in red indicate differences with the ANZECC (2000) guideline trigger values

In situ water quality results for both February and April 2017 at the six Reedy Lake sites (WQ3 excluded) are presented in Table 5. DO remained high at WQ_Inlet, WQ4 and WQM during April and were higher than the ANZECC (2000) guideline. DO also increased at WQ2 and WQ_Outlet during April and also exceeded the ANZECC (2000) guideline. During April, EC decreased at WQ_Inlet, WQ4 and WQM but increased at WQ2 and WQ_Outlet. Despite this, EC remained above the ANZECC (2000) guideline in April. There was some evidence of a decrease in pH at all sites during April with only WQ_Inlet outside the ANZECC (2000) guideline range.

Table 5 *In situ* water quality results from Reedy Lake.

	Temperature (°C)		Dissolved Oxygen (mg/L)		Dissolved Oxygen (%)		Electrical Conductivity (µS/cm)		pH (Units)	
	Feb-17	Apl-17	Feb-17	Apl-17	Feb-17	Apl-17	Feb-17	Apl-17	Feb-17	Apl-17
WQ_Inlet	27.0	18.5	16.1	27.1	218.7	308.9	22,131	17,229	9.5	8.2
WQ1	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
WQ2	17.7	20.8	1.4	15.7	15.7	191.6	16,589	23,450	8.3	8.0
WQ4	23.4	16.1	15.5	16.6	196.7	178.5	21,009	14,756	9.4	7.3
WQM	29.0	17.2	16.8	15.2	237.0	167.1	23,066	14,655	9.8	7.3
WQ_Outlet	20.4	18.6	1.1	10.5	12.7	120.4	10,741	18,371	8.0	8.0
ANZECC (2000) trigger	15 - 35		NA		90 - 110		20 - 30		6.5 – 8.0	

Note: Values in red indicate differences between the ANZECC (2000) guideline trigger values

In situ water quality results from either side of the inlet and outlet gates for both February and April 2017 are presented in Table 6. Note that during April the outlet gate was open so water quality was assessed at a single location due to mixing of the Barwon River and Reedy Lake waters. Similar water temperatures were recorded either side of the inlet and outlet gates during February. During April 2017 temperature on the Reedy Lake side of the inlet gate was 7.4°C colder than the Barwon River side and did not align with the ANZECC (2000) guideline range. Dissolved oxygen was higher on the Reedy Lake side of both the inlet and outlet gates during February 2017 although during April 2017, anoxic water was observed on the Reedy Lake side of the inlet. All dissolved recordings were outside the ANZECC (2000) guideline range due to either high or low concentrations. The differences in DO at the inlet gate during April were supported by ORP which was also significantly lower on the Reedy Lake side.

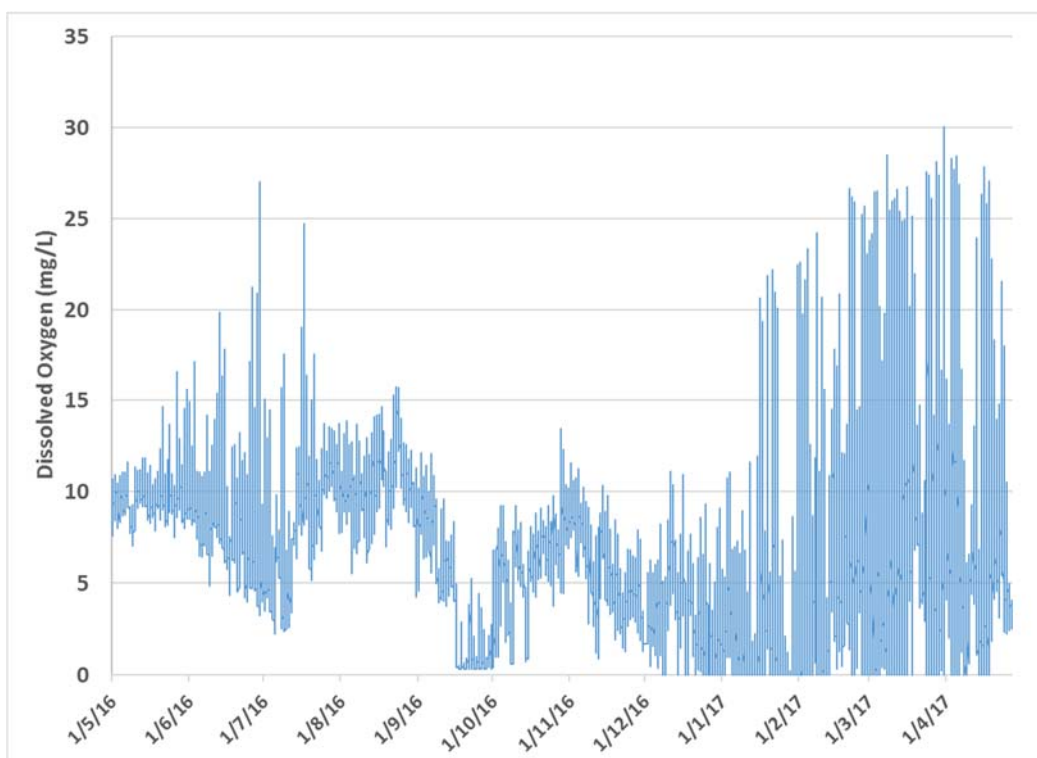
Electrical conductivity was higher the ANZECC (2000) guideline on both sides of the inlet and outlet gates in both months. EC was comparable either side of the outlet gate but during both months EC was noticeably higher on the Reedy Lake side of the inlet gate. None of the pH recordings aligned with the ANZECC (2000) guideline range. While pH was comparable either side of the outlet gate, there were noticeable increases on the Reedy Lake side of the inlet gate, especially during February.

EC and DO levels as recorded at the Reedy Lake gauging station are included in . The continuous recordings confirm that there were increases in EC as water levels decreased and the significant diurnal fluctuations in DO due to the presence of an algal bloom.

Table 6 *In situ* water quality results recorded at the inlet and outlet gates on Reedy Lake.

		Temperature (°C)		Dissolved Oxygen (mg/L)		Dissolved Oxygen (%)		Electrical Conductivity (µS/cm)		pH (Units)		ORP (mV)	
		Barwon	Reedy	Barwon	Reedy	Barwon	Reedy	Barwon	Reedy	Barwon	Reedy	Barwon	Reedy
Feb-17	Inlet	26.0	25.9	6.7	9.2	83.4	117.5	2,598	10,313	6.0	9.0	-81.5	-79.2
	Outlet	24.9	25.2	4.5	5.6	56.9	71.2	12,360	12,412	8.2	8.3	-102.3	-96.9
Apr-17	Inlet	21.2	13.8	10.6	0.0	120.4	0.0	2,341	16,260	8.3	9.0	42.4	-310.8
	Outlet	19.9		13.6		161.3		20,770		8.1		39.2	
ANZECC (2000) trigger		15 - 35		NA		90 - 110		20 - 30		6.5 – 8.0		NA	

Note: *Barwon* indicates recordings taken on Barwon River side of Inlet and Outlet; *Reedy* indicates recordings taken on Reedy Lake side of Inlet and Outlet. Values in red indicate differences between the ANZECC (2000) guideline trigger values



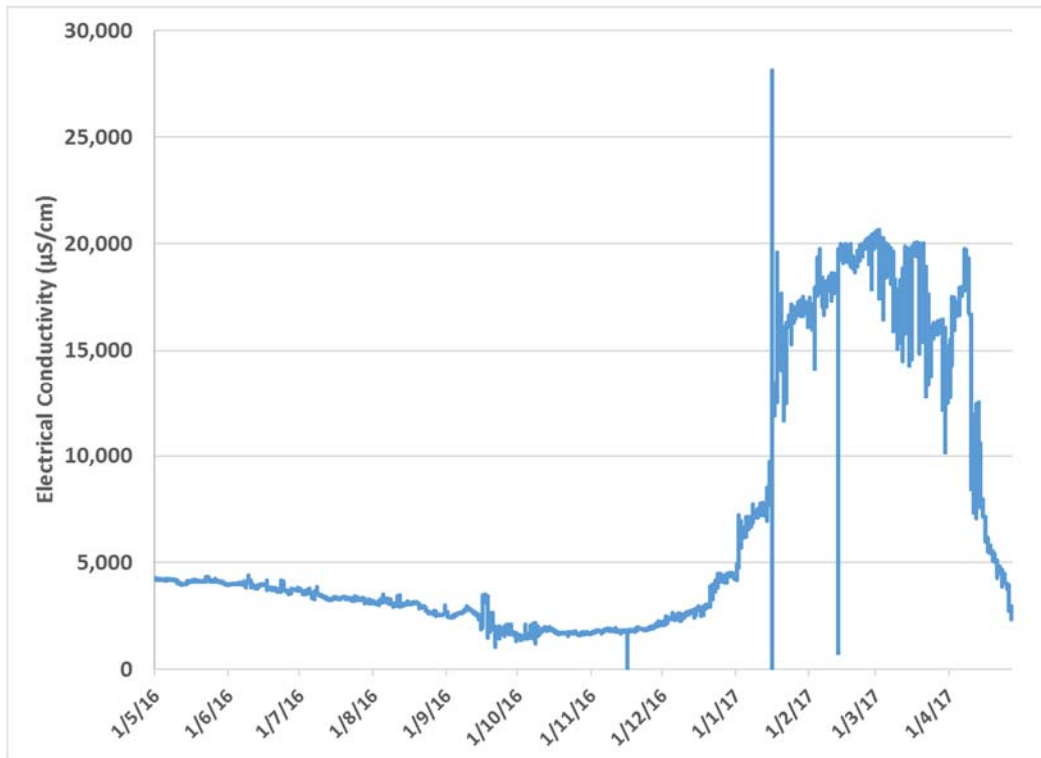


Figure 4 Dissolved oxygen (top) and electrical conductivity (bottom) of Reedy Lake as recorded at gauging station 233603A – Reedy Lake @ Connewarre

The results of the laboratory analyses of surface water quality for both January 2014 and February 2017 at WQM (the deepest area of Reedy Lake) are presented in Table 7. Alkalinity during 2017 was comparable to levels recorded during 2014. However, for all major anions and cations there was a large increase in 2017. Both total and dissolved organic carbon were also higher during 2017. Most of the dissolved metals remained at levels similar to 2014 with the exception of arsenic which was measured an order of magnitude higher in 2017. In both years, all parameters aligned with the ANZECC (2000) guideline with the exception of elevated copper and arsenic during 2017.

Table 7 Laboratory analysed water quality results recorded at WQM

Group	Parameter	ANZECC (2000) trigger	Jan-14	Feb-17
Alkalinity	Hydroxide Alkalinity as CaCO ₃ (mg/L)		<1	<1
	Carbonate Alkalinity as CaCO ₃ (mg/L)		29	<1
	Bicarbonate Alkalinity as CaCO ₃ (mg/L)		233	239
	Total Alkalinity as CaCO ₃ (mg/L)		262	239
Major anions	Sulfate as SO ₄ (mg/L)		34	830
	Chloride (mg/L)		902	7670
Major cations	Calcium (mg/L)		59	217
	Magnesium (mg/L)		76	457
	Sodium (mg/L)		480	3670
	Potassium (mg/L)		11	120
Ionic balance	Total anions (meq/L)		31	238
	Total cations (meq/L)		30	211
	Ionic balance (%)		1.68	6.07
Dissolved metals	Arsenic (mg/L)	0.024	0.016	0.100

Group	Parameter	ANZECC (2000) trigger	Jan-14	Feb-17
	Cadmium (mg/L)	0.0002	<0.0001	<0.0001
	Chromium (mg/L)	0.001	<0.001	<0.001
	Copper (mg/L)	0.0014	0.001	0.002
	Lead (mg/L)	0.0034	<0.001	<0.001
	Nickel (mg/L)	0.011	0.001	0.003
	Zinc (mg/L)	0.008	<0.005	<0.005
	Mercury (mg/L)	0.0006	<0.0001	<0.0001
Organics	Dissolved Organic Carbon (mg/L)		27	43
	Total Organic Carbon (mg/L)		25	59

Note: Values in red indicate differences against the ANZECC (2000) guideline trigger values

3.4.3 Sediment quality

The results of the laboratory analyses of sediment (excluding metals/metalloids) for both February and April 2017 are presented in Table 8. During February water level in Reedy Lake was at 0.12 to 0.13 m while in April it had increased to 0.27 to 0.28 m. It should be noted that due to the low water levels during 2017, site S7 was dry when the sediment samples were collected while S1 and S8 remained wet with water depths of around 30 cm.

Amongst each sediment site total alkalinity was generally consistent and ranged from 69 mg/kg to 85 mg/kg. The majority of alkalinity present in the sediment was in the form of bicarbonate alkalinity with little (<1 mg/kg) in the form of carbonate alkalinity. The high bicarbonate alkalinity levels recorded during 2017 were also found in previous monitoring during 2014 (see GHD, 2015). However, total alkalinity was noticeably higher during 2014 compared to 2017.

During both February and April 2017 there was variation in the concentration of major anions and cations amongst the sites. For example, during April sulfate ranged from 720 mg/kg at S8 to 3,840 mg/kg at S7. During April chloride ranged from 4,540 mg/kg at S7 to 15,800 mg/kg at S8. Furthermore, all major anions and cations were lower in April compared to January. The concentrations of all major anions and cations were elevated in both months during 2017 compared to 2014. At all sites pH ranged from 7.0 to 8.0 suggesting no significant acid generation potential which was also found by GHD (2015) for the majority of sites in Reedy Lake during the baseline assessment.

The results of the laboratory analyses of metals/metalloids in the sediment of Reedy Lake are included in Table 9. It is clear that the concentrations of all metals/metalloids remained low during 2017 with the exception of iron at S1 and S8. The concentration of metals/metalloids at S7 during 2017 were generally lower than or comparable to concentrations recorded during the 10 week simulated drying assessment in 2014. It was not possible to compare concentrations of metals/metalloids measured in 2017 the ANZECC (2000) guideline due to the detection limits used during the laboratory analyses when analysing the samples.

Table 8 Sediment quality results from Reedy Lake.

		S1			S7			S8		
		Jan-14	Feb-17	Apr-17	Jan-14	Feb-17 ¹	Apr-17 ¹	Jan-14	Feb-17	Apr-17
Physico-chemical	pH (Units)		8.0	7.8		7.4	7.0		8.0	7.2
	Electrical Conductivity (µS/cm)		14,200	2,110		12,400	3,410		15,400	2,050
	Moisture Content (%)	46.1	7.9	59.1	6.7	31.7	20.4	38.6	8.3	78.1
Alkalinity & acidity	Total Alkalinity as CaCO ₃ (mg/kg)	339		85	387		12	382		77
	Bicarbonate Alkalinity as CaCO ₃ (mg/kg)	339		85	387		12	382		77
	Carbonate Alkalinity as CaCO ₃ (mg/kg)	<1		<1	<1		<1	<1		<1
	Acidity (mg/kg)		28	10		17	6		170	11
Major anions	Sulfate as SO ₄ ²⁻ (mg/kg)	<50	2,080	820	200	5,100	3,840	60	2,220	720
	Chloride (mg/kg)	660	28,000	8,320	2,980	34,200	4,540	880	30,300	15,800
Major cations	Calcium (mg/kg)	40	510	150	140	1,890	900	80	950	480
	Magnesium (mg/kg)	60	1,480	280	130	1,910	700	80	1,510	640
	Sodium (mg/kg)	640	12,900	4,590	1,410	14,000	3,280	800	14,300	8,040
	Potassium (mg/kg)	90	580	290	80	480	200	50	580	440

1. Note that site S7 was dry during February and April 2017.

Table 9 Metals/metalloids results from Reedy Lake including the simulated leachate drying assessment 2014, and the 2017 monitoring results.

		Simulated drying leachate assessment 2014										2017 Drying					
		22/4/14	29/4/14	6/5/14	13/5/14	20/5/14	27/5/14	3/6/14	10/6/14	17/6/14	24/6/14	28/2/17	4/4/17	28/2/17	4/4/17	28/2/17	4/4/17
		S7	S7	S7	S7	S7	S7	S7	S7	S7	S7	S1	S1	S7 ₁	S7 ₁	S8	S8
	ANZECC (2000) trigger																
Aluminium (mg/L)	0.055	4.58	0.37	0.24	0.38	1.47	0.15	0.04	0.12	0.15	0.01	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Antimony (mg/L)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic (mg/L)		0.016	0.003	0.006	0.007	0.012	0.002	0.003	0.004	0.003	0.004	0.05	0.09	<0.01	<0.01	0.03	0.04
Cadmium (mg/L)	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Chromium (mg/L)	0.001	0.008	<0.001	<0.001	0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper (mg/L)	0.0014	0.004	0.001	0.001	0.003	0.003	<0.001	0.001	0.001	0.001	0.021	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron (mg/L)		4.3	0.22	0.31	0.48	1.87	0.09	<0.05	0.10	0.14	<0.05	0.35	0.09	0.06	<0.05	0.31	0.51
Lead (mg/L)	0.0034	0.004	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.011	0.006	<0.001	<0.001	<0.001	0.002	0.001	0.002	0.001	0.001	0.002	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.00005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/L)	0.008	0.13	0.019	0.022	0.028	0.049	0.02	0.062	0.031	0.035	0.081	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury (mg/L)	0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: Values in red indicate difference with the ANZECC (2000) guideline trigger values. Site S7 was dry during February and April 2017

3.4.4 Groundwater quality

Groundwater sampling was undertaken at three groundwater monitoring bores in April 2017. The physicochemical field parameters are presented in Table 10. The groundwater laboratory results and comparison table from the sampling are included in Error! Reference source not found.. In general, elevated concentrations of copper and zinc were higher than relevant ANZECC, (2000) guidelines in all three groundwater bores, by up to 0.064 mg/L for copper and 0.059 mg/L for zinc. Concentrations of chromium, lead and nickel were also higher than guideline trigger values but this was to a lesser extent by 0.001, 0.003 and 0.004 mg/L respectively. A greater proportion of metals measured in 2014 were elevated above ANZECC (2000) guidelines compared to results in April 2017. Results in 2017 were generally lower than those concentrations measured in 2014.

Total (Bicarbonate) Alkalinity as CaCO₃ remained similar, with a slight increase (between 2 and 30 mg/L respectively) for UB_FG1 and UB_CS1 compared to previous sampling undertaken in 2013, 2014 and 2017. UB_WH1 increased more significantly than the other groundwater bores.

The electrical conductivity indicates saline groundwater, although the salinity levels have reduced since sampling in January 2014. The standing water levels (SWL) in the bores declined at two bores (UB_CS2 and UB_FG1), while UB_WH1 increased.

The dissolved oxygen (DO) levels were higher, ranging from 3.34 mg/L to 4.60 mg/L, compared to the measurements taken in January 2014, which ranged from 0.24 mg/L to 3.17 mg/L. The temperatures were lower during the April 2017 sampling (ranging 16.2°C to 16.9°C), compared with January 2014 sampling where temperatures ranged from 17.7°C to 21.9°C. This could explain the higher DO levels recorded, since when the water temperature increases, DO generally decreases.

Table 10 *In-situ* groundwater quality results

Bore ID	Date	SWL (m)	pH	Electrical Conductivity (µS/cm)	DO (mg/L)	Temp (°C)	Turbidity (NTU)	ORP (mV)
UB_CS2	23/01/14	2.53	7.15	25200	0.24	17.7	23.1	-
UB_FG1	22/01/14	4.93	6.74	22100	3.17	19.4	35.5	-
UB_WH1	22/01/14	2.23	7.16	47500	0.28	21.9	3.20	-
UB_CS2	03/04/17	2.89	7.44	22183	4.30	16.2	-	180.2
UB_FG1	03/04/17	6.72	6.17	19409	3.34	16.3	-	138.1
UB_WH1	03/04/17	1.87	7.20	28333	4.60	16.9	-	60.0

3.5 Discussion

The results collected during the first of the four year environmental watering cycle presented in the *Seasonal Watering Proposal for the Lower Barwon Wetlands 2017 -18* identified variability in water quality as a result of the drying phase. These are discussed in more detail in the following sections, reflecting on the differences between the 2015 baseline data and a comparison with guideline trigger values in ANZECC (2000). The ANZECC guidelines provide direction on acceptable levels of water and sediment quality that are required to support a healthy system at Reedy Lake. This approach has been adopted due to limited water quality data.

3.5.1 Ambient surface water quality

During this investigation, CCMA were able to effectively manage the water levels in Reedy Lake through the use of both the inlet and outlet structures. At the height of drying (January to April 2017) water levels were effectively maintained by CCMA above 0.0 m AHD. This prevented drying of sediment in the deeper sections of Reedy Lake that could have resulted in activation of acid sulphate soils and mobilisation of metals.

During the 2014 baseline assessment of Reedy Lake (GHD, 2015) surface water quality was indicative of a largely brackish environment with slightly alkaline pH which remained through the drying phase. Electrical conductivity (EC) continued to increase through the drying phase and became almost 13 times higher at WQ4 during 2017 compared to 2014. The increase in EC is likely to be related to an increased concentration of salts as water evaporated and to some extent estuarine water through the outlet structure during high tides. It was observed that, even when the outlet structure was closed, some estuarine water was able to flow into the lake system.

Concentrations of pH and EC were regularly higher in both 2014 and 2017 when compared to their respective ANZECC (2000) guideline trigger values. However, the EC guideline (20 to 30 $\mu\text{S}/\text{cm}$) is for freshwater lakes and reservoirs and given that Reedy Lake has estuarine water delivered from the Barwon River due to tidal influences, this trigger value may not be relevant. The relatively high pH in Reedy Lake and subsequent elevation above the ANZECC (2000) guideline may be related to the photosynthesis and respiration of algal communities, particularly during 2017 when a substantial algal bloom was observed (Plate 1). It is not unusual for there to be diurnal fluctuations in pH. This occurs when dissolved carbon dioxide (CO_2) forms carbonic acid and results in a decrease in pH (more acidic). During daylight photosynthesis results in the uptake of CO_2 and a subsequent increase in pH (more alkaline). Alternatively, during night time respiration is the dominant process and dissolved CO_2 can be released back into the water column, thereby reducing pH.

High pH levels in Reedy Lake may also be related to the delivery of estuarine water from the Barwon River. The ANZECC (2000) guidelines suggest that an acceptable range for pH in an estuary is between 7 and 9 and recordings made at the outlet on the Barwon River side found pH ranged 8.2 to 8.3. This, coupled with photosynthesis by the algal bloom, may have contributed to the high pH observed. The high alkalinity observed during the monitoring may also buffer against significant changes in diurnal pH. There were no pH recordings made during the night so the diurnal fluctuation patterns in pH are unknown. High turbidity during 2017 is also likely to be a result of the algal bloom combined with suspended sediment and other detritus in the water column, particularly at the Lake water levels dropped.

Overall, dissolved oxygen (DO) was noticeably higher during 2017 than for 2014 although in both years low concentrations were also observed. The concentration of DO in a waterbody is dependent on the balance between the flux of bioavailable carbon and the rate at which bacteria consume oxygen while decomposing this material, daily inputs of oxygen through diffusion with the atmosphere and via photosynthesis/respiration by macrophytes and phytoplankton (ANZECC, 2000). The high DO concentrations observed are most likely due to the photosynthesis activity of algae in the lake while periods of low concentrations indicate that the biological oxygen demand (BOD) during the breakdown of organic material exceeded photosynthetic rates

Low DO can have a direct adverse effect on many aquatic organisms (e.g. fish, invertebrates and microorganisms) which depend upon oxygen dissolved in the water for efficient biological function (ANZECC, 2000). It can also lead to conditions in sediments, where the sediments release previously-bound nutrients and toxicants to the water column where they may compound existing problems (ANZECC, 2000).

The low oxidation-reduction potential (ORP) observed during 2017 suggest that nutrients and toxicants may have been released from the sediments into the water column. This is supported by the water quality monitoring of site WQM where increases in sulfate, chloride, calcium, magnesium, sodium, potassium and arsenic were observed in 2017 compared to 2014. This is a trend that should be closely monitored during future drying events.



Plate 1 Algal bloom observed in Reedy Lake during 2017

The increase in water levels from January to April 2017 was accompanied by a decrease in EC (excluding WQ2) and pH. The inlet structure remained closed until April 2017 so the increase in water level in April 2017 was not related to inputs from freshwater reaches of the Barwon River. It was likely due to inputs of freshwater from other sources following the high rainfall event in April 2017 (see Figure 3) and the decreases in EC and pH an artefact of dilution. Despite this, DO remained high throughout the lake and the algal bloom persisted.

In situ water quality monitoring either side of the inlet structure highlights that it is an effective barrier to water exchange between the Barwon River and Reedy Lake. In particular, during April 2017 DO was 120% on the Barwon River side of the inlet but was completely anoxic on the Reedy Lake side. Both EC and pH were higher on the Reedy Lake side while ORP was noticeably lower. Water exchange between the outlet structure and Reedy Lake was observed during January 2017 despite the gate being closed. Therefore, complete management of water levels in Reedy Lake is problematic as water losses to the Barwon River and inputs from the estuary into the lake can occur through the outlet.

3.5.2 Ambient sediment quality

During the 2014 baseline assessment, GHD (2015) found that decreases in pH were accompanied by increases in sulfate and the liberation of metals when sediment was dried over time for a number of sites in deeper areas of Reedy Lake. Based on the recommendations of GHD (2015) water levels during this 2016/17 water cycle were maintained above 0 m the prevent risks to Reedy Lake from sediment in the deeper areas being exposed. With this under consideration, the 2017 monitoring of sediment in Reedy Lake was carried out in shallow areas likely to experience a decrease in water level or exposure to enable an assessment of risks from CASS or liberation of metals due to the drying regime.

Although there were increases in the concentration of all major anions and cations during 2017 compare to 2014, pH at all sites ranged from 7.0 to 8.0 suggesting no significant acid generation potential. This was also found by GHD (2015) for the majority of the shallower sites in Reedy Lake and it was suggested that high concentrations of bicarbonate alkalinity has the potential to buffer against changes in pH. During 2017 bicarbonate alkalinity also contributed highly to the overall alkalinity although concentrations were noticeably lower than for 2014.

The baseline assessment of sediment quality by GHD (2015) also detected elevated concentrations of arsenic, mercury and nickel throughout Reedy Lake and these findings were generally consistent with previous monitoring (Alluvium 2013).

The assessment of metals/metalloids done by GHD (2015) and Alluvium (2013) were based on concentrations within the sediment and reported as mg/kg. The 2017 monitoring focussed on pore water concentrations (reported as mg/L) as this provides an estimate of the conditions of the pore water, the reaction rate of the acid generated and the degree of metals liberated during the drying regime. It also enables comparisons to the simulated drying leachate assessment reported by GHD (2015). The 10 week simulated drying leachate assessment was performed in a laboratory in the attempt to replicate sediment behaviour following drying for an extended period.

During the actual drying in 2016/17, it is clear that the concentrations of all metals/metalloids remained low during the drying with the exception of iron at S1 and S8. The concentration of metals/metalloids at S7 during 2017 were generally lower than or comparable to concentrations recorded during the 10 week simulated drying assessment in 2014.

3.5.3 Groundwater monitoring

Elevated concentrations of copper and zinc were measured in all three groundwater bores, above the ANZECC (2000) fresh water quality guidelines. Concentrations of chromium, lead and nickel were also measured above the guidelines, but these were marginal exceedances.

The elevated concentrations when compared to the data collected in January 2014 generally show a reduction in the concentration for many samples. Only two samples in 2017 showed an increase in their concentrations; one was the detection of lead, and the other was an increase of copper at one bore. All results are expected to be within the normal range of background concentrations and are unlikely to adversely impact aquatic biota in their current state.

A network of groundwater monitoring wells exist across the Lake Connewarre Complex with twelve in the Reedy Lake system. Partner researchers from Federation University and RMIT have been involved in the annual monitoring of these wells. Comparison with groundwater monitoring data provided by the partner researchers (unpublished data) and the samples collected by GHD show generally similar results. Total alkalinity (predominately bicarbonate) was the exception, measured higher by GHD in the April 2017 sampling, however was relatively consistent with measured alkalinity by the partner researchers. The GHD data collected in 2014 had the lowest concentrations among the datasets. A noticeable increase was at UB_WH1 in the April 2017 sampling.

Comparison of the metal concentration results amongst the three data sets, the results recorded by GHD were lower compared to the partner researchers in the past. This difference may have been due to a more sensitive laboratory detection limit employed by GHD's nominated laboratory. The recent results collected in April 2017, show generally lower results than the GHD sampling undertaken in January 2014.

3.6 Summary

3.6.1 What do the monitoring results tell us about the 2016-17 wetting and drying regime?

The environmental watering regime implemented during the 2016/17 was programmed to be a complete drying event, scheduled 1 in every 4 years, however, due to the risk CASS generation water levels were maintained above 0.0 m AHD. The drying of Reedy Lake between November 2016 and April 2017 was carried out methodically, and to a large extent seamlessly, with the water receding at a gradual rate.

The results confirm that the highest risk of CASS generation is unlikely to be realised if lake levels are maintained >0.0 m during future drying. This was consistent with the GHD (2015) report. This suggests that future drying events are unlikely to generate acid events or liberate metals from the sediment, which could affect the environmental values of Reedy Lake beyond the short term impacts that may be experienced as the system acclimatises to the altered environment water regime.

3.6.2 Management considerations

At the height of this first drying event in 2016/2017, water levels were maintained above 0 m AHD to prevent significant deterioration of water and sediment quality, activation of CASS and the mobilisation of metals. The results of surface water, sediment and groundwater collected in 2016/2017 indicated that there were marginal, if any, change to the physicochemical conditions in the sediment, surface water and groundwater of Reedy Lake during the low-partial drying regime. CASS was not generated in Reedy Lake and metal concentrations were comparable to ANZECC guidelines. During future drying events, it is critical that water levels in Reedy Lake are not reduced below 0.0 m AHD.

It was evident that CCMA were able to control the water levels by actively managing the inlet and outlet culverts and could manually reintroduce water back into the system as required. Observations and *in situ* water quality results indicated that the inlet culvert was an effective barrier to water exchange between the Barwon River and Reedy Lake. Complete management of water levels in Reedy Lake may be problematic as water losses to the Barwon River and inputs from the estuary into the lake can occur through the outlet. To allow for better management of the water during drying in future years, upgrades to the outlet to prevent water loss is recommended. This will be a partially important management consideration when Reedy Lake is partially dried to 0.3 m AHD.

The management approaches applied during the 2016/2017 drying event, which involved regular visits to Reedy Lake, daily observations of the telemetry meter, and *in situ* water quality measurements by EstuaryWatch, should be as a minimum priority actions for future drying.

Recommendations for future monitoring

To understand the impact of future drying events in Reedy Lake, GHD recommends the following monitoring program:

- The telemetry meter located in Reedy Lake should be maintained in its current position in the Big Hole to record water level, DO and EC. The ability to measure pH should be further explored.
- For the years where Reedy Lake will be partially dried (2 in 4 years) and low-partially dried (1 year in 4) the following monitoring should occur:
 - *In situ* monitoring of surface water at seven locations previously sampled WQ_Inlet, WQ1, WQ2, WQ3, WQ4, WQM and WQ_Outlet on two occasions - prior to drying and also at the height of drying (where surface water is present).

- Laboratory analysis of sediment collected from S7 at the height of partial and low drying.
- Laboratory analysis of sediment collected from S1 and S8 during low-partial drying (1 in 4 years)
- Groundwater monitoring of UB_FG1, UB_CS1 and UB_WH1 at the height of partial and low-partial drying.
- Analysis of surface water, sediment and groundwater is not required during the full water year with the exception of results collected by the telemetry meter.
- Results should continue to be compared to the baseline data collected by GHD (2015) and subsequent results collected during the nominated partially and low-partially dry years.

Data collected from Reedy Lake by the EstuaryWatch volunteers is extremely valuable. Depending on the availability of volunteers and accessibility of Reedy Lake, it is recommended that during the drying events, *in situ* data including pH is collected at a frequency of monthly. This data will provide further information to capture any changes in the physicochemical state of the Lake during the environmental watering regime that can feed into the baseline understanding of the system.

4. Fish monitoring

4.1 Objective

The objective of the fish monitoring component of the project was to determine diversity, abundance and age classes of the fish community in Reedy Lake. The survey was not intended to be comprehensive or to provide a pre/post analysis of fish movement with regard to the drying regime. Rather the intent was to determine what species were present and their biological relationship with Reedy Lake. Age class data was aimed at improving the understanding of the dynamics of the system, water velocity impacts on small-bodied fish, and the movement of fish between the carp screen and vertical slot fishway. Ultimately, the results from the survey will provide information for stakeholders and assist with management decisions made by the CCMA.

4.2 Background

There is little known information about the species, abundance and distribution of finfish in Reedy Lake. The results of the Victorian Biodiversity Atlas (VBA) database search for existing records of aquatic species within a 10 km radius of Reedy Lake indicated that a total of 46 fish and crayfish species, or their habitat, have been reported from within a 10 km radius of Reedy Lake. Results are presented in Table 11.

The PMST search tool identified the vulnerable Dwarf Galaxias (*Galaxiella pusilla*), Yarra Pygmy Perch (*Nannoperca obscura*) and Australian Grayling (*Prototroctes maraena*) or their habitat is also likely or known to occur within 10 km of Reedy Lake. Of the three species identified by the PMST search tool, only Dwarf Galaxias were not identified by the VBA search. This species has been included in Table 11.

Of all species identified from the database searches, only freshwater and estuarine fish and crayfish species with the potential to occur within Reedy Lake have been considered further. Given that the 10 km search radius extends into Port Phillip Bay, it is not surprising that estuarine and marine fish were identified in the search. As Reedy Lake is subject to tidal influences from the Barwon River, estuarine and marine species were retained in the search results, as their presence cannot be ruled out.

Table 11 Victorian Biodiversity Atlas database search results indicating existing records of species within a 10 km radius of Reedy Lake

Scientific Name	Common Name	EPBC List	Victorian Advisory List	FFG List	Origin
<i>Euastacus yarraensis</i>	Southern Vic. Spiny Crayfish				Native
<i>Engaeus fultoni</i>	Otway Burrowing Crayfish		VU		Native
<i>Engaeus cunicularius</i>	Granular Burrowing Crayfish				Native
<i>Engaeus sericatus</i>	Hairy Burrowing Crayfish		VU		Native
<i>Geotria australis</i>	Pouched Lamprey				Native
<i>Anguilla australis</i>	Southern Shortfin Eel				Native
<i>Hyperlophus vittatus</i>	Sandy Sprat/Whitebait				Native
<i>Oncorhynchus mykiss</i>	Rainbow Trout				Introduced
<i>Salmo trutta</i>	Brown Trout				Introduced
<i>Retropinna semoni</i>	Australian Smelt				Native
<i>Prototroctes maraena</i>	Australian Grayling	L	VU	VU	Native
<i>Galaxias truttaceus</i>	Spotted Galaxias				Native

Scientific Name	Common Name	EPBC List	Victorian Advisory List	FFG List	Origin
<i>Galaxias brevipinnis</i>	Climbing Galaxias				Native
<i>Galaxias maculatus</i>	Common Galaxias				Native
<i>Galaxias pusilla</i>	Dwarf Galaxias	L	EN	VU	Native
<i>Carassius auratus</i>	Goldfish				Introduced
<i>Cyprinus carpio</i>	European Carp				Introduced
<i>Gambusia holbrooki</i>	Eastern Gambusia				Introduced
<i>Melanotaenia fluviatilis</i>	Murray River Rainbowfish	L	VU		Native
<i>Atherinosoma microstoma</i>	Small-mouthed Hardyhead				Native
<i>Gymnapistes marmoratus</i>	Soldierfish				Native
<i>Ambassis agassizii</i>	Agassiz's Glassfish	L	RX		Native
<i>Macquaria australasica</i>	Macquarie Perch	L	EN	EN	Native
<i>Macquaria colonorum</i>	Estuary Perch				Native
<i>Nannoperca obscura</i>	Yarra Pygmy Perch	L	VU	VU	Native
<i>Nannoperca australis</i>	Southern Pygmy Perch				Native
<i>Perca fluviatilis</i>	Redfin				Introduced
<i>Sillaginodes punctatus</i>	King George Whiting				Native
<i>Pomatomus saltatrix</i>	Tailor				Native
<i>Pseudocaranx georgianus</i>	Silver Trevally				Native
<i>Arripis trutta</i>	Eastern Australian Salmon				Native
<i>Acanthopagrus butcheri</i>	Black Bream				Native
<i>Argyrosomus japonicus</i>	Mulloway				Native
<i>Girella tricuspidata</i>	Luderick				Native
<i>Gadopsis marmoratus</i>	River Blackfish				Native
<i>Aldrichetta forsteri</i>	Yellow-eye Mullet				Native
<i>Mugil cephalus</i>	Sea Mullet				Native
<i>Pseudaphritis urvillii</i>	Congolli/Tupong				Native
<i>Afurcagobius tamarensis</i>	Tamar Goby				Native
<i>Arenigobius bifrenatus</i>	Bridled Goby				Native
<i>Tasmanogobius lasti</i>	Scary's Tasman goby				Native
<i>Philypnodon grandiceps</i>	Flathead Gudgeon				Native
<i>Rhombosolea tapirina</i>	Greenback Flounder				Native
<i>Tetractenos glaber</i>	Smooth Toadfish				Native
<i>Tandanus tandanus</i>	Freshwater Catfish	L	EN		Native
<i>Tinca tinca</i>	Tench				Introduced

L = EPBC Listed; VU = Vulnerable; EN = Endangered; RX = Regionally Extinct

4.3 Methods for Monitoring

4.3.1 Survey of fish communities

Fish communities were surveyed prior to the implementation of the drying regime on 2 and 3 of November 2016 to establish baseline conditions. Multiple techniques were adopted for the fish survey including boat electrofishing, bait trapping and seine netting. Boat electrofishing was carried out in open water areas of Reedy Lake (e.g. Plate 2) with particular attention given to the Big Hole as depth limited the ability to survey in other areas. The electrofishing occurred in a 4.3 m aluminium punt using a 7.55 GPP Smith-Root boat mounted electrofisher.

Bait traps (unbaited) were also deployed at random locations in the littoral zone of the open water areas. In addition to the boat electrofishing and bait trapping of open water areas, seine netting was carried out in shallow areas (<30 cm) of Reedy Lake (e.g. Plate 2). The seine netting occurred at an inundated shallow area at the end of Fitzgerald Road and Moolap Station Road.



Plate 2 Example of an open water area where boat electrofishing and bait trapping occurred (left) and shallow area habitat where seine netting occurred (right)

4.3.2 Carp impact assessment

To assist in addressing community concern regarding the growing impact of Carp on aquatic vegetation and native fish species in the Big Hole during the drying regime, several assessments of Carp numbers was made during the drying regime. These included:

- Using a smaller boat an additional visual and more extensive survey of the Big Hole was carried out on 28 February 2017. Visual assessments for Carp were also made at the inlet gate and outlet gate to Reedy Lake.
- At the height of drying on 21 March 2017, a visual survey of the Big Hole was carried out as an alternate method with Carp numbers counted in areas that permitted passage of the boat.. It was originally planned to conduct the survey using boat electrofishing. However, the shallow nature of the lake due to the drying regime made this impossible as the boat could not be navigated.
- Based on the results of the previous two visual surveys, on April 2017 the entire length of the outlet channel was visually surveyed to determine if schools of Carp were present within the channel.

4.4 Results

4.4.1 Survey of fish communities

Water levels during the November 2016 fish survey were in the range of 1.02 to 1.06 m. A total of 327 individuals from 11 species were retrieved from Reedy Lake during the November survey (Table 12). European Carp were the numerically dominant fish species, retrieved followed by Common Galaxias and Small-mouthed Hardyhead. Four of the fish species are introduced with seven species native. Four of the native species are migratory.

Table 12 Number of fish retrieved during the November 2016 survey

Common Name	Species Name	Native	Migratory	Big Hole & open water areas	Fitzgerald Rd	Moolap Station Rd	Total
Small-mouthed Hardyhead	<i>Atherinosoma microstoma</i>	Yes	No		26	7	33
Common Galaxias	<i>Galaxias maculatus</i>	Yes	Yes	1		83	84
Tamar Goby	<i>Afurcagobius tamarensis</i>	Yes	No	2	1	21	24
Sea Mullet	<i>Mugil cephalus</i>	Yes	Yes			1	1
Tupong	<i>Pseudaphritis urvillii</i>	Yes	Yes	2			2
Flat-headed Gudgeon	<i>Philypnodon grandiceps</i>	Yes	No	4			4
Short-finned Eel	<i>Anguilla australis</i>	Yes	Yes	2			2
Mosquitofish	<i>Gambusia holbrooki</i>	No	No		12		12
Redfin Perch	<i>Perca fluviatilis</i>	No	No	13	2		15
European Carp	<i>Cyprinus carpio</i>	No	No	128	23		151
Goldfish	<i>Carassius auratus</i>	No	No	2			2

The average lengths of the fish species retrieved from Reedy Lake are included in Figure 5. There was a large amount of variation in the length of European Carp which ranged from 10 to 725 mm. However, the results in Figure 5 are based on all individuals retrieved and when the locations are considered separately smaller individuals were retrieved from the shallow inundated margins of the lake at Fitzgerald Road and Moolap Station Road (average length 17 ± 7 mm) with larger individuals within the open water areas (average length 500 ± 117 mm). There was also some variation in the size of Redfin (average length 252 ± 143 mm) and the Short-finned Eels (average length 525 ± 106 mm).

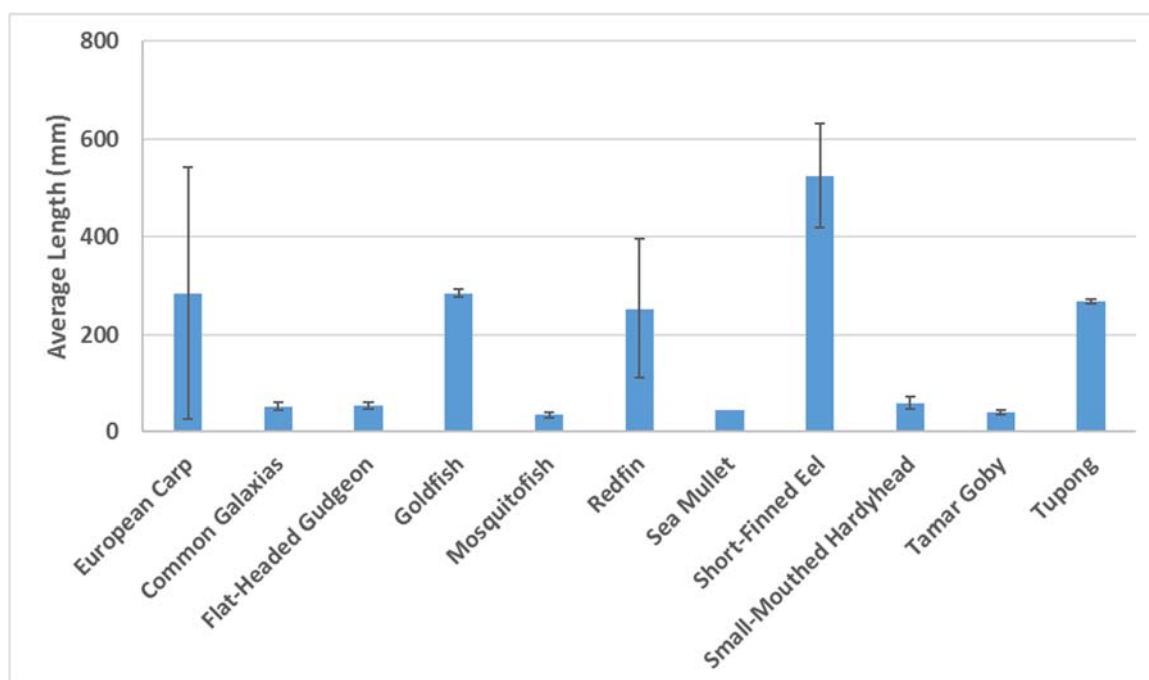


Figure 5 Average length ± standard deviations of fish species retrieved during the November 2016 survey

4.4.2 Carp impact assessment

During the first carp impact assessment on 20 February 2017 water level in Reedy Lake was in the range of 0.19 to 0.21 m. An attempt at boat electrofishing was made but the shallow nature of the lake prevented this. A visual survey of Carp was undertaken but none were sighted.

A further and more intensive visual survey of the Big Hole was carried out on 28 February 2017 (water level 0.12 to 0.13 m). Only three adult Carp were sighted in the Big Hole during this subsequent survey. Visual assessments for Carp were also made at the inlet gate and outlet gate to Reedy Lake during this survey and while only a couple of dead Carp were sighted at the inlet gate, hundreds of adults were aggregated at the outlet gate (Plate 3). As the gate was closed at this point, it appears that the outlet gate acted as a barrier to the Carp exiting Reedy Lake and entering the Barwon River. A large school of Common Galaxias were also sighted at the outlet gate during February 2017 (Plate 3).

On 29 March 2017 GHD again visited the inlet and outlet channels to visually survey for Carp although none were sighted (water level 0.17 to 0.22 m). It was assumed that the Carp had either moved out of the Reedy Lake system into the Barwon River (the boards to the outlet had been removed) or had returned to Reedy Lake. To validate this an additional visual survey was carried out on 3 April 2017 (water level 0.27 to 0.28 m) throughout the Big Hole and the entire length of the outlet channel. No adult Carp were sighted within the Big Hole but a school of Carp remained within the outlet channel.



Plate 3 Reedy Lake fish communities 28 February 2017. Dead and decomposing Carp at the inlet channel (left) and schools of adult Carp and Common Galaxias at the outlet channel (middle and right)

4.5 Discussion

4.5.1 Ecological database search

Of the 11 fish species retrieved in the fish surveys (see 4.4.1), all were identified in the database searches so there were no cryptic or unexpected species found in Reedy Lake during the 2016/17 surveys. None of the four crayfish species identified in the database searches were retrieved during subsequent fish surveys of Reedy Lake.

4.5.2 Survey of fish communities

Fish communities were surveyed prior to the implementation of the drying regime to establish baseline conditions. Eleven fish species were retrieved from Reedy Lake and all species have previously been reported from the region (e.g. Hall & Tunbridge, 1988; Zampatti & Koster, 2002; Environous, 2008; Ryan, *et. al.*, 2010). More recently, the Arthur Rylah Institute for Environmental Research (DELWP) conducted a fish survey of the Barwon River in the vicinity of the tidal barrage. Species retrieved from Reedy Lake that were not found in the Barwon River were Tamar River Gobies, Sea Mullet, European Carp and Goldfish. Alternatively, ARI found Climbing and Spotted Galaxias, Golden Perch, Short-headed Lamprey, Southern Pygmy Perch, Australian Mudfish, Australian Grayling, an unidentified Goby, and Australian Smelt. These species were not found in Reedy Lake, although based on the database search, the majority have previously being found in the region. The exceptions being Golden Perch, Short-headed Lamprey and Australian Mudfish.

Within Reedy Lake, European Carp were the numerically dominant fish species retrieved followed by the native Common Galaxias and Small-mouthed Hardyhead. It was found that large bodied carp (average length 500 ± 117 mm) resided within the deeper areas of Reedy Lake with smaller bodied individuals (average length 17 ± 7 mm) in the shallow inundated margins. This may be related to the spawning behaviour of Carp given that they are potamodromous during spring and can spawn in floodplain wetlands (Harris, 2013). However, Smith and Walker (2004) found evidence in the River Murray that the Carp spawning period can range from September through to the following May.

The smaller bodied Carp, of which there were 44, may represent the young of the year for 2016 that remained in the inundated margins of the lake. This is supported by Carp aging studies in Australia that have found that 0+ year old fish can be up to approximately 180 mm in length while fish in the range of 500 mm may be greater than 6 years old (Vilizzi & Walker, 1999; Donkers, 2011).

Of the native species found in Reedy Lake, a brief outline of some of their life history strategies and tolerances are included in Table 13. Based on this information, it is not anticipated that there would be a major impact on the native fish species present within Reedy Lake should the water level be maintained at 0 m or above. Regarding the timing of the gate closure and the potential impacts on fish species the following points apply:

- Potential impacts on Redfin, Mosquitofish, Goldfish and Carp have not been considered as they are exotic species and management of Reedy Lake would not be aimed at maintaining their communities;
- Based on migration periods to facilitate spawning, closure of the gate over the summer period should not interrupt lifecycles;
- Sufficient habitat would be retained in Reedy Lake following the closure of the gate;
- There may be an increase in competition for resources and predation of native fish species (e.g. by carp) once water levels decrease and fish are concentrated;
- All fish species can tolerate a range of salinities;
- The main threat to the fish communities would most likely be related to adverse water quality, especially pH, dissolved oxygen and the formation of algal blooms, associated with the drying regime;
- Maintaining water levels at >0.0 m would create adverse water quality and potential threats to fish communities; and,

- Given that most fish species were recorded by ARI in the Barwon River, the loss of species in Reedy Lake would potentially be replaced through recruitment from the Barwon River once the gate is opened.

Table 13 Brief description of some strategies and life-history traits of native fish species found in Reedy Lake

Species	Strategies and life-cycles
Small-mouthed hardyhead	Small-mouthed hardyhead are short-lived and breed from September to October before dying soon afterwards. The pelagic larvae hatch after 5-7 days. They are highly euryhaline and can tolerate a broad range of salinities. They prefer estuarine sea-grass habitats or areas with aquatic vegetation.
Common Galaxias	<p>Common Galaxias live in a range of environments, usually in still or slow-flowing waters within a short distance of the sea. They are sometimes found in brackish streams and can tolerate salinities up to 50 ppt.</p> <p>These fish migrate downstream and spawn in estuaries, laying their eggs amongst dense vegetation either in flooded banks of streams or estuaries flooded by the high spring tides. When the tides recede, the eggs survive and develop aurally in these moist environments for two to four weeks until the next spring tides. After hatching larvae are washed out to sea and develop in the open ocean after about 6 months before returning to the rivers where they hatched the following spring.</p> <p>Land-locked individuals migrate upstream to spawn in the tributaries during late winter to early spring when water levels rise. After hatching, the larvae are washed downstream into lakes, usually developing amongst near-shore vegetation.</p>
Tamar Goby	Tamar goby's are found in estuaries, coastal lakes and the lower parts of rivers where they make burrows in silty or muddy bottoms and in seagrass beds. They spawn in spring and females deposit adhesive demersal eggs onto hard surfaces such as rocks or logs. Parents guard the eggs until they hatch.
Sea Mullet	The sea mullet is euryhaline and can tolerate different levels of salinity. They are predominately found in estuaries or inshore waters but can occur in freshwater areas of coastal streams. Spawning occurs at sea from autumn to early winter. Larvae enter estuaries and juveniles live in shallow sheltered waters. Some reside in freshwater, especially if there are barriers to returning to estuaries, and can persist in such environments for long periods. From late summer to early winter adults leave estuaries and return to the ocean.
Tupong	The species can be found in fresh, brackish, and marine waters and lives mostly in estuaries and streams. They live in amongst snags, over hanging banks, and leaves that have falling into the water. Between late April and August they migrate to estuaries and breed.
Flat-headed Gudgeon	The species is found in fresh and brackish waters with muddy bottoms and aquatic vegetation. They may also be found in slow flowing streams and usually spawns from Spring to Summer.
Short-finned eels	Adults may remain in freshwater environments for 10-20 years or even longer, before migrating to the sea to breed and then die. In Victoria, juveniles move into estuaries and rivers from around May to October where they acclimate to reduced salinities and develop rapidly into elvers. This is followed by a secondary upstream migration into freshwater. They can move over land during damp conditions.

Species	Strategies and life-cycles
Australian Smelt	A schooling species found in slow flowing/still fresh water habitats such as lakes, dams and billabongs. They shoal near the surface or around the cover of aquatic plants and woody debris. They can also inhabit swamps, backwaters, brackish estuaries and inland salt lakes. Individuals mature in their first year and spawn between July and March. Generally, the entire lifecycle is completed in freshwater.

4.5.3 Carp impact assessment

The main aim of the Carp impact assessment was to assist in addressing community concern regarding the growing impact of Carp on aquatic vegetation and native fish species in the Big Hole during the drying regime. Observations of Carp and the water quality conditions of Reedy Lake has allowed Carp movement to be summarised (Figure 6). This can be used to understand Carp movement during the drying regime and to identify the best approach for Carp eradication and management.

At the height of the drying regime a large school of adult carp were sighted within the outlet channel and became aggregated at the outlet gate which acted as a barrier. Individuals that had aggregated at the inlet gate perished due to the decline in water quality as a result of being disconnected from the lake and high levels of evaporation at this location. It is assumed that Barwon River estuarine water that was able to pass through the outlet gate maintained a suitable quality of water. This may have also acted as a cue for the Carp to move towards the outlet channel boards.



Figure 6 Conceptual model of carp movement during the summer drying regime of 2016-17

4.6 Summary

4.6.1 What do the fish survey results tell us about the 2016-17 drying event?

The results of the 2016-17 monitoring of the diversity, abundance and age classes of the fish community in Reedy Lake has enabled some insight into the current communities utilising the lake and the movement of Carp prior to and during the drying regime.

European Carp were the numerically dominant fish species (particularly in deeper areas), followed by the native Common Galaxias and Small-mouthed Hardyhead. Smaller bodied, immature carp remained in the inundated margins of the lake after drying. The surveys indicated that there would be no major impact on native fish species should the water level be maintained at > 0 m. Closure of the gate over the summer period should not interrupt lifecycles, sufficient habitat would be retained in Reedy Lake following the closure of the gate. All fish species recorded can tolerate a range of salinities, and any reduction in native fish populations in Reedy Lake would potentially be replaced through recruitment from the Barwon River once the gate is opened.

4.6.2 Management considerations

When considering future drying years, the following threats to native fish in Reedy Lake should be considered:

1. increased competition for resources and predation of native fish species (e.g. by carp) once water levels decrease and fish are concentrate.
2. adverse water quality, especially pH, dissolved oxygen and algal blooms associated with the drying regime. Maintaining water levels at >0.0 m would limit adverse water quality conditions and reduce impacts of potential threats to fish communities.
3. dropping water levels too quickly, stranding fish in isolated littoral zones which are suitable nursery areas. The rate the water levels are reduced during the drying events could be managed to ensure fish have adequate time to exit.

Surveillance and monitoring of carp movement during the drying regime identified opportunities for eradication of carp when water levels are low throughout the lake and carp congregate in the outlet channel. At the height of the drying regime Carp can be targeted within the outlet channel. To successfully target the Carp at this time the outlet should remain closed to act as a barrier and prevent movement into the Barwon River. To limit carp movement back into the lake additional stop-nets (wire barrier) could be placed at various points towards the upstream extent of the outlet channel. Carp could be moved towards the inlet channel and harvested at the Outlet culverts which supports access for vehicles and machinery. Harvesting could be undertaken using purpose built carp cages that would trap carp and allow movement of native fish.

Ultimately, the eradication of Carp from Reedy Lake can occur throughout the year although eradication during the drying regime may allow for a more targeted, efficient and cost-effective approach. If eradication was to occur outside of the drying regime (e.g. May to mid-November) intensive boat electrofishing of Reedy Lake coupled with seine netting of inundated littoral areas would be required to effectively target both adult and juveniles.

4.6.3 Recommendations for future monitoring

To confirm if the findings of the current monitoring are consistent in future years and to increase knowledge on fish communities within Reedy Lake to inform future management, the following considerations for future monitoring are recommended:

- The survey methods applied during 2016/2017 could be repeated in subsequent drying years to confirm the distribution of native and exotic within the Big Hole and inundated littoral areas;
- The inundated littoral areas were found to provide suitable habitat for both exotic fish (esp. juvenile Carp) as well as several native species. These nursery areas are lost due to the drying regime but the consequence on fish inhabiting these areas is unknown. Monitoring the movement of fish out of such areas as water levels drop would help inform the risk to fish communities during future drying events;
- Prior to the opening of the inlet and/or outlet gates, a survey of the inlet and outlet channels should be completed. Physical measures such as cages could be installed that support harvesting carp from the outlet channel. Mesh sizes of cages should support movement of native fish.

5. Waterbird monitoring

5.1 Objective

The objective of the bird monitoring component of this project was to collate the baseline data that exists for water birds, which are an integral part of Reedy Lake's ecology and character. The information collected and summarised will also provide sufficient information that can allow for future monitoring comparisons of bird populations. The collation of historic data and ongoing regular waterbird monitoring at Reedy Lake using standard techniques and methods will assist with medium to long term wetland management.

5.2 Background

Depending on conditions and water levels in particular, Reedy Lake offers a wide range of habitats for birds, including deep open water, shallow water, dense reed beds, saltmarsh, marshy ground and mudflats. This habitat diversity attracts a diversity of waterbirds and wetland-associated land birds. As a now-permanent or semi-permanent wetland, Reedy Lake provides foraging and refuge habitat for waterbirds during dry periods elsewhere. Because many waterbirds in south-eastern Australia rely on a network of wetlands, even wetlands used occasionally can be important under some conditions (Watkins and AWSG 1993). Despite its Ramsar listing, Reedy Lake is currently a Game Reserve, where shooting of birds is permitted during the open season.

5.2.1 History of bird monitoring at Reedy Lake

Birds at Reedy Lake have been observed and monitored since the 1890s. Historical accounts vary in their content and level of detail. In recent decades, the lake has been the site of various organised and methodical surveys, including wader surveys (1981 – present) and the Reedy Lake Study (1997 – 2000), and currently, members of the Geelong Field Naturalists Club (GFNC), in association with Birdlife Australia (BLA), conduct twice-yearly monitoring of all birds at the Lake, including waterbirds and waders. There have also been numerous important bird observations recorded by individuals on an *ad hoc* basis.

Mackenzie *et al.* (2006) reports 148 species use Reedy Lake, based on data compiled from a range of sources stemming back to the early 1900s (Appendix B). Waterbirds at the lake are well known and well documented, while land-based birds at the lake are less well known.

5.2.2 Bird-monitoring locations at Reedy Lake

Reedy Lake is a large wetland, and much of it is accessible only by boat.

Most observations of birds (particularly waterbirds) have been made at a small group of locations around the perimeter of the lake where there is road access. . Other observations are made from boats in the deeper parts of the lake and along the water channels that provide boat access between the shore and the deeper area (Big Hole).

The most commonly reported locations and types of bird sare identified below(from Mackenzie *et al.* (2006):

- Moolap Station Road and surrounds – on the north side of the Lake, this location is known for a wide variety of birds, particularly its waders (shorebirds), dabbling ducks, and uncommon species (Brolgas, Magpie Geese, historically Orange-bellied Parrots, among others).

- O'Halloran Road and surrounds – on the east and south-east side of the Lake, this location is known for a similarly wide variety of birds as the Moolap Station Road area, but tends to have smaller numbers.
- Woods Road area – on the west side of the Lake, this location tends to attract a wide variety of birds, but is best known for as the site for the first Australian record of a Lesser Yellowlegs.
- Big Hole (typically accessible by boat only) – the deepest part of the lake, and a large lagoon surrounded by reedbeds. Best known for large numbers of waterfowl, particularly diving and dipping species (Musk Duck, Blue-billed Duck, Hardhead, grebes, cormorants, Australasian Darter, Australian Pelican, Eurasian Coot), and colonial nesting/breeding by Straw-necked Ibis, Australian White Ibis and Royal Spoonbill, and occasionally Great Cormorant.

5.2.3 Important characteristics of birds at Reedy Lake

Some of the important characteristics of waterbirds documented for Reedy Lake are:

- Fifty-three species are of special conservation status and/or have significant populations that use Reedy Lake (Table 3 in Mackenzie *et al.* 2006). These include 20 species for which Reedy Lake is of regional significance, 24 species for state significance, 1 for national significance, and 2 for international significance.
- Reedy Lake appears to have been an important location for visiting migratory waders (shorebirds), but the number of shorebirds visiting the lake varies with conditions (see Section 5.2.1). Reedy Lake does not appear to be particularly important for over-wintering shorebirds - water levels at the lake tend to be high in winter, and potential feeding areas for waders tend to be flooded. The year 1996 was a notable anomaly – 262 Red-necked Stints and 220 Curlew Sandpipers were counted at the lake in winter (June) (Mackenzie *et al.* 2006).
- The most numerous migratory shorebird at the lake historically is the Sharp-tailed Sandpiper. Highest counts of that species suggest that the lake is internationally important (4170 birds counted in 1985, which is more than 1% of the estimated global population). Reedy Lake is also nationally significant and a local stronghold for Marsh Sandpiper (130 counted in 1983).
- Reedy Lake is an important breeding location for a number of waterbirds, particularly Australian White Ibis, Straw-necked Ibis, and Royal Spoonbill, but also Musk Duck, Black Swan and Purple Swamphen. In addition, some regionally significant species breed there, particularly Magpie Goose (since 2002) and Brolga.
- From the 1970s onwards, Reedy Lake has hosted breeding colonies of Straw-necked Ibis, Australian White Ibis, and Royal Spoonbill, mainly around the Big Hole. However, numbers of nests vary enormously from year to year, with historical data ranging from many thousands (19,000 in 1978) to none at all. Initiation of breeding and breeding success requires high water levels in the lake during spring.
- Other uncommon species that occur at the lake include Australasian Bittern, which occurs in relatively large numbers in the tall reeds and rushes.

In addition to the waterbirds, Reedy Lake is one of the most important regional breeding areas for land birds associated with wetlands, including Swamp Harrier, White-fronted Chat, Little Grassbird, Golden-headed Cisticola, and Clamorous Reed-Warbler. Land-based birds are less well understood than the water-based birds at the site, as the focus has always been on the lake's value as a wetland habitat (Mackenzie *et al.* 2006).

The lake (in conjunction with Lake Connewarre) is considered a nationally and internationally important wetland for the Orange-bellied Parrot - 11 birds were observed at Reedy Lake in 1998. In view of the dramatic population declines of this species in recent years, whether this species continues to use Reedy Lake as a preferred site remains unknown.

Bird life at Reedy Lake seems to be characterised by occasional proliferations and irruptions of certain species. Over the years, 15 species have been reported at the Lake in numbers greater than 1000 individuals. These species (with the number of observations of >1000 birds in parentheses) are:

Australian Shelduck (1)	Australian White Ibis (2)	Sharp-tailed Sandpiper (7)
Pacific Black Duck (7)	Straw-necked Ibis (6)	Silver Gull (1)
Australasian Shoveler (2)	Purple Swamphen (1)	Whiskered Tern (1)
Grey Teal (7)	Eurasian Coot (13)	Welcome Swallow (1)
Chestnut Teal (2)	Red-necked Stint (1)	Common Starling (non-native) (1)

Other than for ibis and spoonbills, Mackenzie et al. (2006) suggests that the lake is generally not important for breeding, and is more typically a foraging and refuge area.

Mackenzie *et al.* (2006) notes increases in some bird populations at Reedy Lake since the early 1900s, including species such as Magpie Geese, Australasian Darter, Eastern Great Egret, Intermediate Egret, Cattle Egret and Brolga.

Mackenzie *et al.* (2006) notes no consistent decreases in bird populations, even though the highest numbers of three migratory shorebirds (Curlew Sandpiper, Red-necked Stint and Sharp-tailed Sandpiper) were seen in 1985, and have not been recorded in similar numbers since.

5.2.4 Variability in bird counts at Reedy Lake

Wader counts at Reedy Lake

As part of the National Wader Count (RAOU and Australasian Waders Studies Group), wader (shorebird) species have been monitored at Reedy Lake since 1981. Mackenzie et al. (2006) reports summer and winter count data from 1981 – 2006, and those data (Figure 7 and Figure 8) show that shorebird abundance and species richness at Reedy Lake vary greatly from one year to the next. Summer counts of individuals ranged from 7533 birds (of 12 species) in 1985, to 18 birds (of 1 species) in 1993. Winter counts are consistently lower than summer counts (most species are migratory, and absent from Australia during the winter months), and ranged from 563 birds (of 7 species) in 1996, to 3 birds (of 1 species) in 1999. The most numerous migratory shorebird at the lake historically is the Sharp-tailed Sandpiper, by far. Highest counts of that species suggest that the lake is internationally important (4170 birds counted in 1985, which is more than 1% of the estimated global population) (Mackenzie *et al.* 2006).

Determining long-term patterns or trends in such variable data is difficult. However, the decade of the 1980s saw the three highest wader (summer) counts of the entire reported period, and the numbers recorded in the 1990s and early 2000s seem to be considerably lower (Figure 7). The exception is 2004, with a single count of >1000 birds, which was atypically high during that period.

The numbers of wader species that visit the lake appears to be loosely tied to the overall count of birds (Figure 8). That is, when waders are present in large numbers, there also tends to be more species present. The obvious anomaly here is 1994-1995, where relatively high species richness of waders was not matched by relatively high abundance.

The winter wader count in 1996 was also a notable anomaly at Reedy Lake. In June that year, 262 Red-necked Stints and 220 Curlew Sandpipers were counted at the lake (Mackenzie *et al.* 2006).

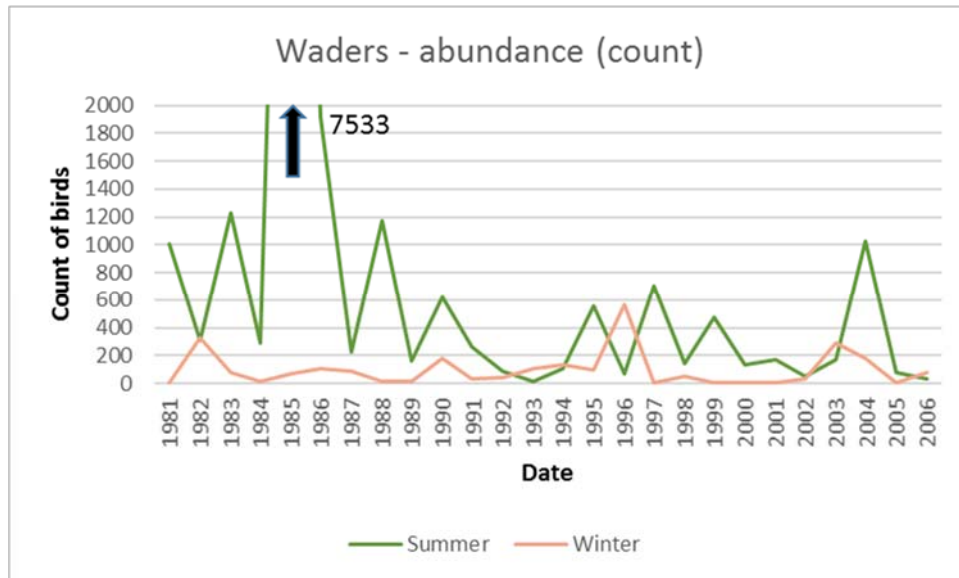


Figure 7 Summer and winter counts of wader (shorebird) individuals at Reedy Lake 1981-2006 (from Table 1, Mackenzie *et al.* 2006)

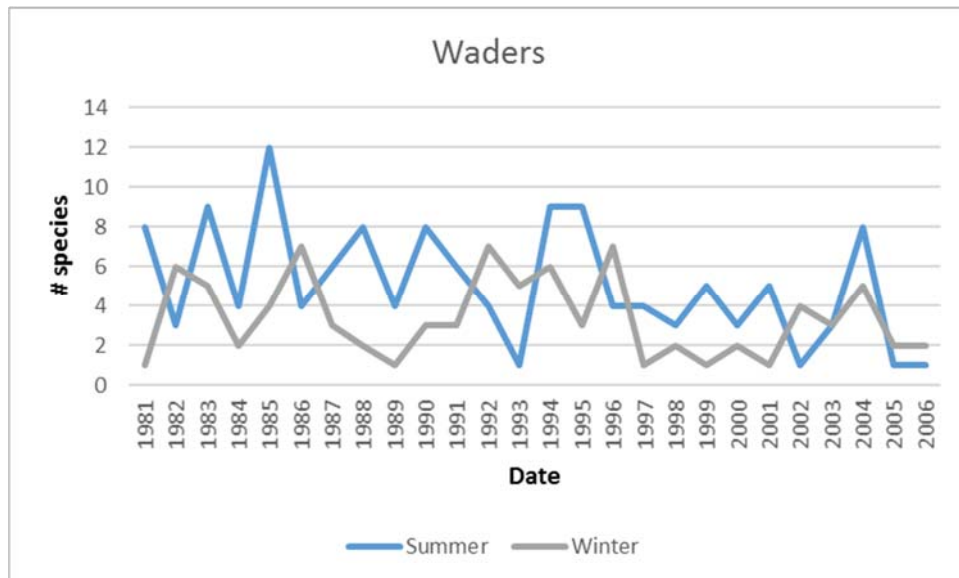


Figure 8 Summer and winter counts of wader (shorebird) species at Reedy Lake 1981-2006 (from Table 1, Mackenzie *et al.* 2006)

Waterfowl counts at Reedy Lake

Department of Sustainability and Environment (DSE) summer waterfowl counts between 1987 and 1992 provide another demonstration of high variability in waterbird numbers at Reedy Lake. Waterfowl (swans, geese, ducks, grebes and coots) abundance and species richness at Reedy Lake vary from one year to the next, but waterfowl appear to remain at the lake in consistently higher numbers. Summer counts ranged from 4986 birds (of 11 species) in 1991, to 2662 birds (of 11 species) in 1987. The highest measured species richness during this period was 14 species in 1989.

Variability in waterfowl numbers do not appear to fluctuate as much as waders, mainly because the lowest counts for waders were near zero, while for waterfowl they remain above 2500.

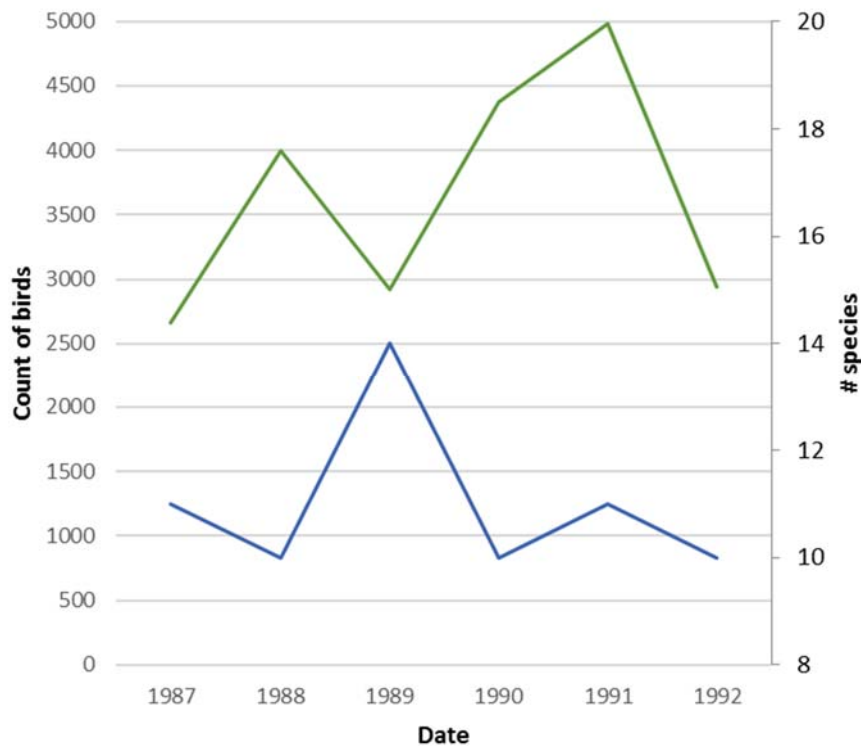


Figure 9 Summer counts (individuals, green line; species, blue line) of waterfowl at Reedy Lake 1987-1992 (from Table 2, Mackenzie et al. 2006).

The Reedy Lake Study

The Reedy Lake study involved a series of bird surveys (water bird and land bird) between 1997 and 2000, on foot from the shore between Woods Road and the channel outlet regulator, and from a boat along channels from the outlet regulator across Big Hole.

Results of the Reedy Lake Study showed no obvious pattern between abundance of waterbirds and water level at Reedy Lake, other than there being few birds observed at times when the lake was very dry (e.g., April 1998) (Figure 10). However, there were other times when equally few birds were observed, and water level was higher (e.g., October 1998, April 1999 and August 2000) (Figure 10), so low water levels are not clearly linked to abundance of waterbirds.

When waterbird species richness was considered (Figure 11), there was again no clear pattern with water level. Some of the waterbirds observed (e.g., gallinules, bitterns, ibis) are dependent on the wetland vegetation rather than the water itself, and this is likely to lessen any pattern if present.

Numbers of land birds also showed no clear change with water level (Figure 10, Figure 11). Most of the land birds observed at Reedy Lake are resident species, so less inclined to dramatic fluctuations in population size.

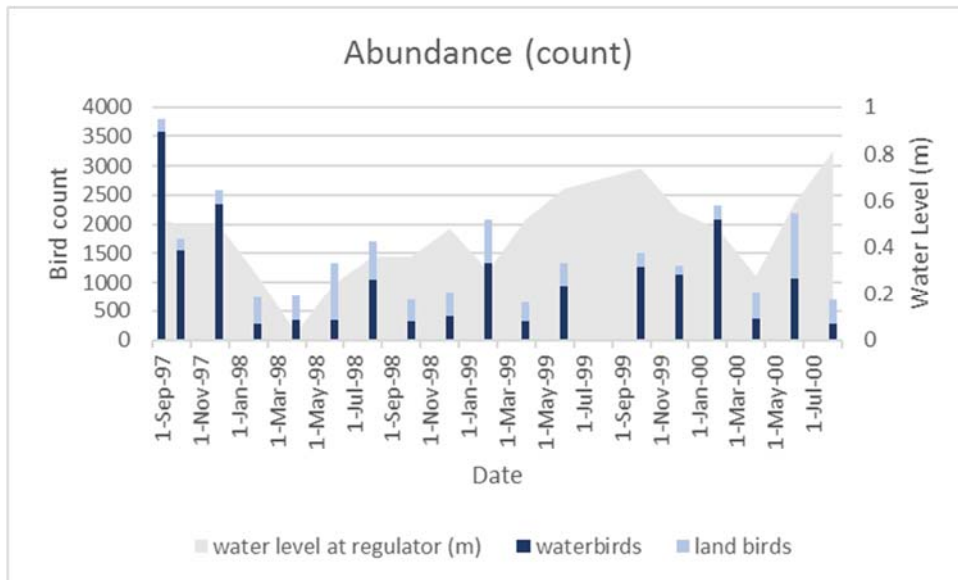


Figure 10 Counts of birds (individuals) and water levels during the Reedy Lake Study (1997 – 2000). From Table 4 (Mackenzie et al. 2006).

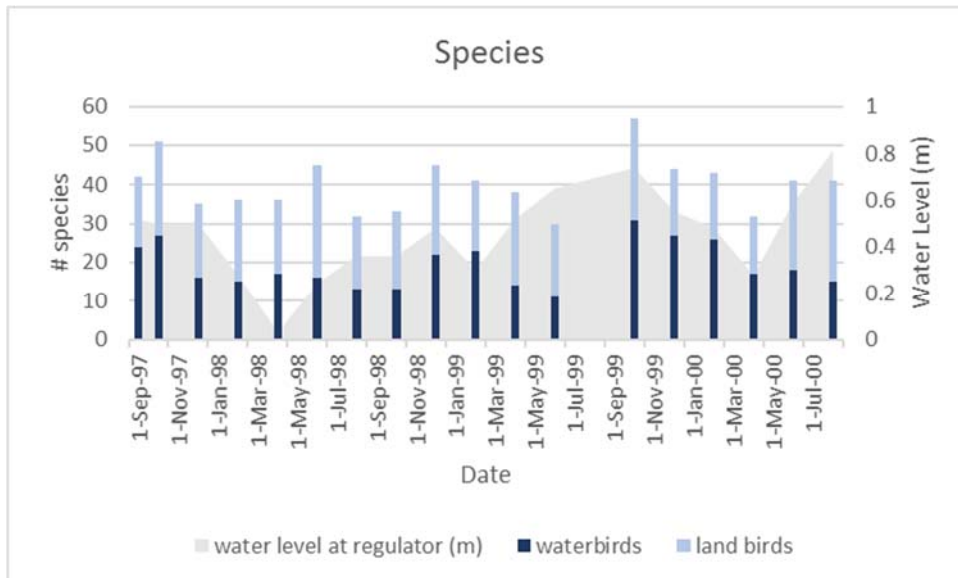


Figure 11 Counts of bird species and water levels during the Reedy Lake Study (1997 – 2000). From Table 4 (Mackenzie et al. 2006).

5.3 Method - Establishing baseline data and a monitoring program

Birds at Reedy Lake have been observed and monitored since the 1890s and there is a vast amount of historical bird data. The numbers of birds that use Reedy Lake vary greatly.

To establish baseline data, and meaningful future comparisons, monitoring needs to focus on dominant and detectable patterns in bird life, rather than some of the less common or less obvious occurrences. The more frequent the monitoring is, and the longer the duration of the monitoring program, the more those unusual observations will be recorded.

A monitoring program is likely to be undertaken by volunteers such as GFNC, and it is important that the established monitoring efforts and timing are manageable and acceptable to those volunteers and adequate for the project's objectives.

For GFNC, the primary purpose of volunteering time and effort to observe and count birds at Reedy Lake is to contribute to a wider survey of the whole Connewarre/Lower Barwon complex for BirdLife Australia database and BirdLife Atlas. In conjunction with BirdLife Australia, GFNC have been counting shorebirds at Reedy Lake since 1981 at a frequency of twice yearly, adding waterbirds in 2003.

The following proposed monitoring program was written on the basis of historical records of birds at Reedy Lake, and includes:

- quarterly surveys (Jan – Mar; Apr – Jun; July – Sept; Oct - Dec) at five land-based locations (Moolap Station Rd, Woods Rd, Coppards Rd, Fitzgerald Rd, O'Halloran Rd); and,
- twice-yearly surveys (Jan – Mar and Sept - Dec) at three water-based locations relatively central to Reedy Lake.

5.3.1 Methods for monitoring

Stepwise methods used for monitoring birds at Reedy Lake are as follows:

- Observers meet at vehicles at a site and organise binoculars, cameras, spotting scope, insect repellent, hat, footwear, as required;
- Observers assess birds that can be seen/heard from that location, with a focus on waterbirds seen and/or heard towards the wetland and flying overhead;
- Observers walk slowly and quietly towards the lake centre as a loose group, recording birds observed along the way. The distance walked varies and is limited by water extent and depth, and vegetation growth (particularly tall *Typha* and *Phragmites*).
- For all birds seen, a record is kept (usually by a nominated 'recorder') of species and count. Other information was collected by GFNC in January 2017, and this will provide important contextual information, but is not critical to the long-term monitoring program, which is seeking quantitative measures of change. Additional information included (where relevant and as far as possible): sex, age class, plumage moult, behaviour, evidence of breeding.
- While looking for birds, observers remain within contact distance of one another, and consult regularly, but each observer follows his own meandering transect to search different sections of the habitats. Interesting sightings are made known to each other, and observers tend to converge for those observations.
- In January, the GHD ecologist carried a hand-held GPS unit to record survey effort, distance walked and time spent, but the GFNC members do not do this routinely. Because the distance and track walked are likely to vary and have the greatest influence on which birds are recorded, CCMA should provide GFNC with a GPS unit for this purpose.
- All habitats within view are assessed for birds, but the focus is the wetland habitats. Observers tend to be watching keenly for some of the more secretive and small wetland species (e.g., crakes and rails, small waders), and this means that the search effort for all species is very high. Note, too, that the counting of bush birds does not influence the results of waterbird findings, but needs to be recognised when interpreting the data (i.e., when comparing numbers of species seen at different times).
- When observers feel they have collectively exhausted the observations in that area (i.e., no new species showing up), they return to the vehicles, usually walking more quickly, but still observing and recording birds (trying not to re-count birds already recorded) along the way.

- Once back at the vehicles, observers move on to the next site to repeat the process there (note: on January 21, observers met first at Fitzgerald Road, which is the furthest site from Geelong/Melbourne, and progressively moved westwards via the north, ending at Coppards Road).

5.4 Results of bird monitoring

On 21 January 2017, a GHD ecologist accompanied three GFNC volunteers on the first land-based survey conducted as part of this monitoring program. At the time of monitoring, the lake had been drained and the normally-wet bird habitat was very dry.

Six locations were visited, and representative photos of these are shown in the following table. Generally, these are the sites that are visited most by bird observers, including the GFNC and BirdLife members when they conduct their regular monitoring for waterbirds, waterfowl and/or waders. Visiting this suite of sites generally enables at least some sampling of birds in nearly all of the fringing habitats represented at the Lower Barwon Wetlands (as presented in Lloyd Environmental, 2012), including Reedy Lake: Shallow water (<0.3 m deep), Intertidal zones, Supratidal/flood zones, Mud and sand flats, Emerging and fringing vegetation, and Saltmarsh.

The land-based surveys did not include access to the deeper and open water habitats: deep and open water (>0.3 m deep), Aquatic vegetation.





 <p>Fitzgerald Rd</p>	 <p>Moolap Station Rd</p>
 <p>O'Halloran Rd</p>	 <p>Woods Rd</p>



Figure 12 Study sites for bird monitoring

5.4.1 Results of birds observed

Overall, 536 birds of 41 species were counted at Reedy Lake on 21 January 2017 (Table 14). The observations include 142 birds of 15 wetland-associated birds and 394 birds of 26 non-wetland-associated birds.

Numbers of species seen at the different sites varied, ranging from single individuals at one site only (five species: Grey Butcherbird, Red Wattlebird, Red-rumped Parrot, Royal Spoonbill, Whistling Kite) to 46 individuals spread across all six sites (Superb Fairy-wren). The most numerous bird seen was the Welcome Swallow (161 individuals spread across four sites) which is an aerial insectivore, and while not a true wetland-associated species, is likely to be attracted to Reedy Lake by large numbers of insects that emerge from the wetland.

Of the six sites visited, there was a great deal of variation in numbers of birds and species seen. Fitzgerald Road had the highest species and individual bird count, with 232 individuals of 30 species. Woods Road had the lowest counts, with 18 individuals of nine species.

The count of birds (individuals) and species at a site was influenced by the duration spent at that site, with longer search time generally resulting in more birds being counted (Figure 12 upper). Observations at two sites (Woods Road and Moolap Station Road) did not fit this pattern; searches at those sites were of intermediate duration yet returned the fewest birds. Results at those sites are likely to have been influenced by the types of habitats available and the water extent at and near those sites.

When results are presented as bird and species counts per unit time, there are interesting patterns (Figure 12 lower). Shorter visits resulted in maximum counts of species and individuals per unit time, which suggests that most species and individuals are readily observable upon arrival. Longer visits resulted in more species and more individuals being counted (Figure 12, upper), but the rate of accumulation slowed with time. This suggests that the accumulation of species and birds recorded at these sites is rapid early on then diminishes. Detecting major or broad-scale changes in the bird life at Reedy Lake is likely to be detected even with rapid visits to sites. Detection of more subtle responses by less common species will require more concerted monitoring efforts.

Three of the species seen in January 2017 were not recorded for Reedy Lake in Mackenzie *et al.* (2006): Yellow Thornbill, Brown Thornbill and Noisy Miner. This likely reflects the wetland focus of historical bird observations at the lake.

The list of 148 birds compiled for Reedy Lake by Mackenzie *et al.* (2006) includes 88 wetland-associated species and 60 non-wetland-associated species (Appendix B). On 21 January

2017, approximately 17% of the wetland-associated species and 43% of the non-wetland-associated species were recorded.

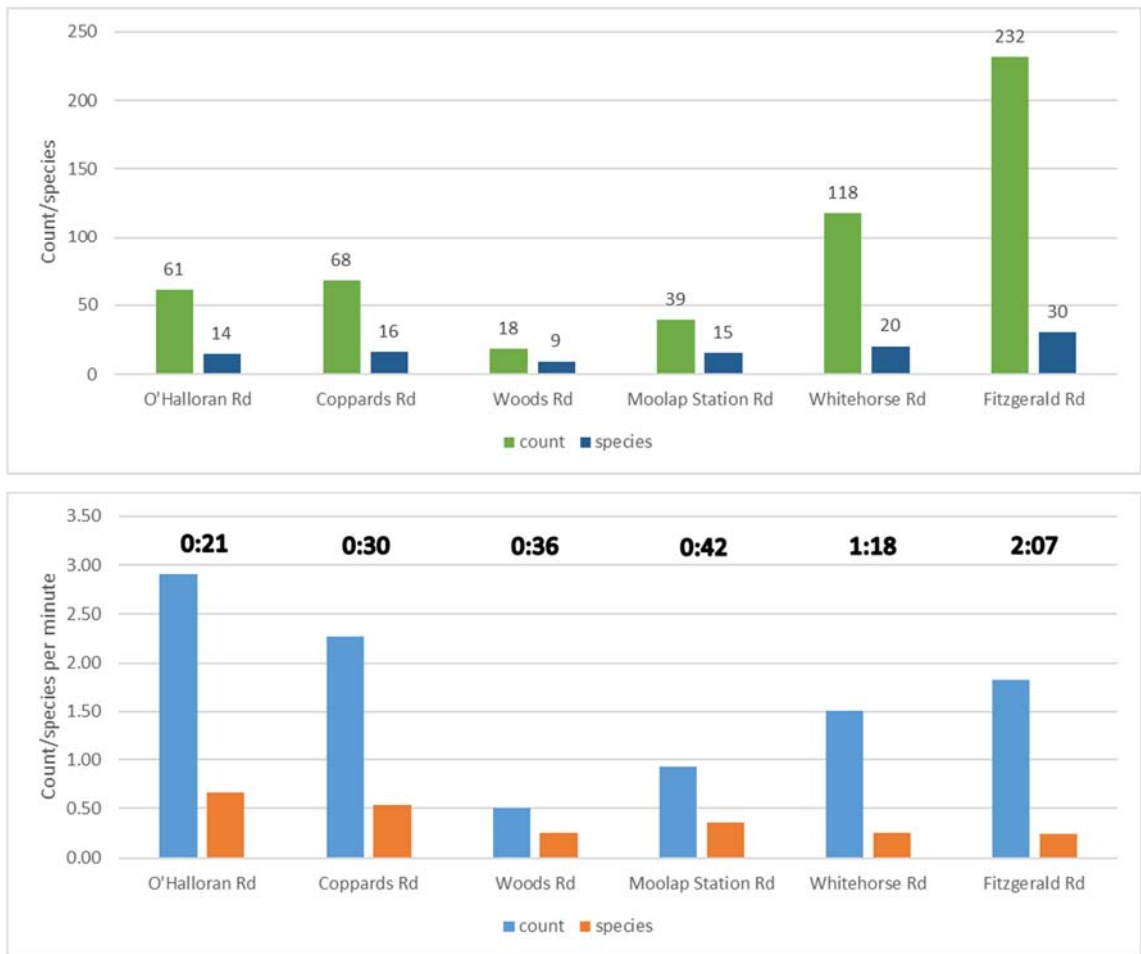


Figure 13 Counts of birds and species at the sites visited, presented as raw numbers (upper graph) and as rates per minute (lower graph).

Duration spent at each site is in bold at the top of the lower graph.

Table 14 Results of bird monitoring (counts of waterbirds and land birds) at Reedy Lake on 21 January 2017.

Species Name	Scientific name	Wetland-association?	Total count	No. sites	Fitzgerald Rd	O'Halloran Rd	Whitehorse Rd	Moolap Station Rd	Woods Rd	Coppards Rd
Purple Swamphen	<i>Porphyrio porphyrio</i>	Y	6	2	5		1			
Australian Pelican	<i>Pelecanus conspicillatus</i>	Y	31	4	16	5	5	5		
Masked Lapwing	<i>Vanellus miles</i>	Y	4	2			2			2
Australian White Ibis	<i>Threskiornis molucca</i>	Y	4	2			2	2		
Royal Spoonbill	<i>Platalea regia</i>	Y	1	1	1					
Yellow-billed Spoonbill	<i>Platalea flavipes</i>	Y	3	1	3					
White-faced Heron	<i>Egretta novaehollandiae</i>	Y	14	5	6	1	3	2		2
Australian Shelduck	<i>Tadorna tadornoides</i>	Y	4	1	4					
Swamp Harrier	<i>Circus approximans</i>	Y	14	5	6	1	4		1	2
Whistling Kite	<i>Haliastur sphenurus</i>	Y	1	1			1			
Brown Falcon	<i>Falco berigora</i>		7	5	2	2	1	1		1
Galah	<i>Eolophus roseicapilla</i>		2	1	2					
Eastern Rosella	<i>Platycercus eximius</i>		3	2				1	2	
Red-rumped Parrot	<i>Psephotus haematonotus</i>		1	1	1					
Welcome Swallow	<i>Hirundo neoxena</i>		161	4	100	10	47			4
Willie Wagtail	<i>Rhipidura leucophrys</i>		12	4	3		6	1		2
Magpie-lark	<i>Grallina cyanoleuca</i>		7	3		2	4		1	
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>		3	1				3		
White-fronted Chat	<i>Epthianura albifrons</i>	Y	23	4	9		6	2		6
Yellow Thornbill	<i>Acanthiza nana</i>		2	1	2					
Brown Thornbill	<i>Acanthiza pusilla</i>		3	2	2			1		
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>		26	3	4	4				18
White-browed Scrubwren	<i>Sericornis frontalis</i>		2	2	1				1	
Striated Fieldwren	<i>Calamanthus fuliginosus</i>	Y	7	2	6		1			

Species Name	Scientific name	Wetland-association?	Total count	No. sites	Fitzgerald Rd	O'Halloran Rd	Whitehorse Rd	Moolap Station Rd	Woods Rd	Coppards Rd
Little Grassbird	<i>Megalurus gramineus</i>	Y	2	1	2					
Clamorous Reed Warbler	<i>Acrocephalus stentoreus</i>	Y	3	1	3					
Golden-headed Cisticola	<i>Cisticola exilis</i>	Y	25	5	10	7	5		1	2
Superb Fairy-wren	<i>Malurus cyaneus</i>		46	6	14	2	6	10	6	8
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>		8	3			2	4		2
New Holland Honeyeater	<i>Phylidonyris novaehollandiae</i>		9	4		2	2	2		3
Noisy Miner	<i>Manorina melanocephala</i>		2	1				2		
Red Wattlebird	<i>Anthochaera carunculata</i>		1	1	1					
Red-browed Finch	<i>Neochmia temporalis</i>		2	1	2					
Little Raven	<i>Corvus mellori</i>		23	4	3	3	15			2
Grey Butcherbird	<i>Cracticus torquatus</i>		1	1	1					
Australian Magpie	<i>Gymnorhina tibicen</i>		27	5	5	16	2	2	2	
European Skylark	<i>Alauda arvensis</i>		5	3	1				2	2
Spotted Turtle-dove	<i>Streptopelia chinensis</i>		2	2	1			1		
European Goldfinch	<i>Carduelis carduelis</i>		5	2		2	3			
House Sparrow	<i>Passer domesticus</i>		26	4	16	4			2	4
Common Starling	<i>Sturnus vulgaris</i>		8	1						8
	<i>Total count</i>		536	6	232	61	118	39	18	68
	<i>Total species</i>		41		30	14	20	15	9	16
Time spent (h:mm)					(2:07)	(0:21)	(1:18)	(0:42)	(0:36)	(0:30)

5.5 Discussion

Birds at Reedy Lake have been observed and monitored since the 1890s and there is a vast amount of historical bird data. The numbers of birds that use Reedy Lake vary greatly. Therefore, as noted by Mackenzie et al. (2006), it is difficult to determine long-term trends in numbers, unless changes are particularly dramatic. It is also difficult to determine whether changes in bird numbers at Reedy Lake are influenced by changing water levels at the lake or by changes in habitat availability and/or quality elsewhere.

The monitoring in January 2017 encountered very dry conditions at the lake. Consequently, a lower number of waterbirds were seen and no shorebirds/waders were seen other than Masked Lapwings (17% of the wetland-associated species and 43% of the non-wetland-associated species were recorded).

This typifies the variability in bird populations at Reedy Lake which respond differently to wet or dry conditions and will also influence future monitoring results.

Based on the implementation of the environmental water regime at Reedy Lake there are a number of outcomes that may occur as a result of implementation of a wetting and drying regime. This could include:

- Return of migratory waders (shorebirds) which will be dependant on the seasonal timing of wetland drying, and the condition and availability of alternative habitat elsewhere.
- Breeding by wetland-dependent species, particularly ibis and spoonbills as Reedy Lake was historically a large rookery for ibis and spoonbills. During January 2017, ibis and spoonbills were observed, but only in small numbers.
- In addition to waterbirds, some of the non-waterbirds species that use wetland habitats are likely to be affected by water regime changes. Changes in populations of some of these species (e.g., Striated Fieldwren) to gains and losses in habitat may be just as informative to the monitoring program as changes in true waterbird populations (e.g., ducks, herons, egrets).

As noted by Mackenzie et al. (2006), it is difficult to determine long-term trends in numbers, unless changes are particularly dramatic. Even without the added complication of changing water levels, the value and usefulness of historical data for establishing baseline data for Reedy Lake are limited by the fact that the data collected and the data-collection methods have not been consistent over the years or projects.

Alignment of monitoring approaches

The current bird survey methods involve land-based surveys only at a range of locations. While these provide practicable (i.e. easy access, repeatable) they do not incorporate access to or monitoring of the Big Hole, which historically has shown itself to be an important waterbird habitat (breeding location for Straw-necked Ibis, Australian White Ibis, Royal Spoonbills). Ideally, the twice-yearly monitoring would incorporate a third, boat-based assessment, either concurrently or at another time, ideally late spring. Water-based surveys would provide a means to document birds using deeper areas that cannot be observed from the land. Currently, boat-based surveys are unlikely to be done by GFNC regularly, and collaboration with Geelong Field and Game for boat access appears unlikely to occur, given the conflicting interests of the groups. It is likely the numbers of volunteers conducting surveys will vary (group size depends on the number of volunteers that turn up on the day), there is likely to be observer bias in the data that result. However, this influence is expected to be minimal, because the approach used by the GFNC team tends to be thorough and not greatly time-constrained.

The monitoring teams tend to adapt their route to conditions encountered, following potential bird habitats and moving around natural obstructions (e.g., deep water), rather than following set monitoring routes or transects. Thus, the drier conditions in January allowed the team members to access parts of the lake that are normally inaccessible. This variability in effort/method is not considered to influence results, because this allows observers the freedom to seek the best bird habitats, as the birds would do when foraging.

The observers also invest considerable time and effort trying to find all birds that may be present, and counting every individual bird seen. Rather than 'measuring' birds in representative sub-samples of the lake (e.g., repeatable fixed-length transects), this approach is more an effort to sample every bird present in that part of the lake. So long as this approach is repeated each time, the results can be considered to be comparable.

Thus, for the suggested monitoring program, there will be consistency in:

- Minimum suite of sites visited
- Time of year
- Information recorded
- Data reliability

There will be variation in:

- The number of observers (most likely ranging from 2 – 5 persons)
- The exact route walked/surveyed (determined largely by observations, weather and water extent)
- Time spent per location (determined mostly by observations and weather – poor weather and sparse birds will lead to quicker site visits)

These constraints are common for ecological monitoring data, and future monitoring efforts at Reedy Lake need to work with this and attempt to standardise the effort each time, so that data comparisons are meaningful. Ideally, the search effort and numbers of observers for each survey would be consistent to provide comparable data. Surveys that are repeated using similar effort, methods and seasonal timing will serve to paint a clearer longer-term picture of the birds at the lake, and allow more opportunity for comparison with current observations.

5.6 What do the water bird results tell us about the 2016-17 drying event?

Given the very low water level at Reedy Lake on 21 January 2017, observations of shorebirds and waterbirds were low compared to the total number of species previously recorded at Reedy Lake. The general absence of shorebirds and waterbirds indicates a short-term response by the birds to the lowered water level, and should not be considered a long-term response to the onset of the altered watering regime.

Monitoring over time will identify how the changes in water levels influence the presence of waterbird and non waterbird species at the lake.

5.7 Management considerations

The current monitoring program has commenced at a time when lake levels from a drying regime that had a lower area of shallow water limiting foraging habitat for a range of species. Reedy Lake provides four key habitats which favour different waterbird guilds. Habitats include deep/open water, shallow water <30cm, Reed beds and shoreline mudflat.

Implementation of the wetting and drying regime in accordance with the ecological objectives and hydrological requirements (water levels and rise and fall of water levels) will provide suitable habitat for waterbirds. Management of vegetation through implementing the wetting and drying regime will provide improved habitat quality and extent for waterbird species.

5.8 Recommendations for future monitoring

The focus for monitoring needs to be long-term rather than short-term. Bird responses are likely to be subtle and gradual, with intermittent and potentially unrelated stochasticity. The bird surveys that are already being conducted by GFNC members provide the basis of a monitoring program that is convenient, achievable and adequate for the purposes of the project, so is recommended for continuation here. More frequent monitoring (e.g., quarterly) would be better than twice-yearly, but may not be sustainable or achievable each year for the volunteers concerned. The benefits of retaining the existing program are: local knowledge and site experience, consistency in methods and in observers, demonstrated commitment to bird monitoring by those who will conduct the monitoring (i.e., 'ownership' of the task), and comfort in the fact that the monitoring will get done with a high level of competence – i.e., the results can be trusted.

As currently proposed, the monitoring program outlined in Section 5.3 will provide consistency in sites visited, time of year of monitoring, information recorded and data quality and reliability. There will be variation in factors such as the number of observers, the exact route surveyed, and time spent per location. These are not likely to affect the results of the monitoring, which aims to detect broad and enduring changes in bird populations at the lake.

The following recommendations are made in an effort to maximise the value of the information that is collected during the monitoring:

- If additional monitoring events are possible for GFNC, then another event in early summer or late spring might be rewarding, and a boat-based event to the Big Hole would be beneficial.
- Ideally, the twice-yearly monitoring would incorporate a third, boat-based assessment, either concurrently or at another time, ideally late spring. Water-based surveys would provide a means to document birds using deeper areas that cannot be observed from the land.
- The timing of the summer bird monitoring is important, and should endeavour to coincide with breeding events at the Lake, which are likely in spring and early summer.

Analysis of data in future needs to consider:

- Consistency in a species' presence/absence (whether a species is recorded at all, and the proportion of monitoring events in which it is recorded)
- Consistency in a species' abundance (how many of a species are recorded? How variable is this number?)
- Consistency in a species' distribution (how many sites does this species occupy? How variable is this distribution?)

The GFNC's historic data for birds at the wetland will also be very useful, particularly when coupled with CCMA data on variation in water level from year to year.

Because the distance and track walked are likely to vary and have the greatest influence on which birds are recorded, CCMA should provide GFNC with a GPS unit for this purpose.

6. Amphibian monitoring

6.1 Objective

Baseline frog monitoring at Reedy Lake was initiated to establish a frog monitoring program. The baseline monitoring was also initiated to understand the species present in Reedy Lake prior to the environmental watering regime commencing. The data will inform the CCMA of species present, the broad habitats used by frogs, the relative size of populations, and appropriate locations and frequency for future surveys.

6.2 Background

Until 2016, little was known about frogs at Reedy Lake. The Victorian Biodiversity Atlas (VBA) contains a register of 16 records of four species: Spotted Marsh Frog (1), Common Froglet (7); Southern Brown Tree Frog (5); and Growling Grass Frog (3), which is surprisingly low given that many birdwatchers and naturalists visit Reedy Lake.

Billows and Gywther (2007) identified five frog species during surveys conducted in September 2007. All five species were heard on the eastern shore of Reedy Lake (Fitzgerald's Road), including the nationally threatened Growling Grass Frog (*Litoria raniformis*). This was the only location where the Growling Grass Frog was encountered in Reedy Lake. The Spotted Marsh Frog (*Limnodynastes tasmaniensis*) was the most widespread species, being encountered at all sites during the targeted survey.

6.3 Methods

Given the frog species expected to be present at Reedy Lake, two acoustic assessments: one in November/December targeting the Growling Grass Frog, and another in late winter (July-September) have been conducted. This report outlines the methods and results of the surveys.

For the December assessment, surveys commenced after sunset, around 21:00 hrs each night. Sites were visited in the order presented in Table 15 on 1 December 2016, then visited in reverse order on 6 December to reduce bias associated with time-of-night. For the September assessment, surveys commenced after sunset around 18:00 hrs, and sites were visited in the order presented in Table 15.

Each night, acoustic surveys were land-based, but at most sites the ecologists walked in towards the lake edge (i.e., towards the water) to assess more distant frog calls, but only where it could be accessed safely. Surveys involved the following approach for each site:

- Listening for calling frogs at that location for at least 10 minutes. All species heard were recorded, and estimates of abundance were also recorded.
- For the November/December survey, particular focus was placed on detecting the Growling Grass Frog, *Litoria raniformis* (GGF); the survey was timed to be during the species' main activity period. The GGF is a threatened species that has been recorded from a few locations along the eastern edge of the lake, but whose population status at the lake is largely unknown; and
- Call playback (December 2016 only) – after the initial listening period, call playback for GGF (broadcast of GGF calls through a loud speaker) was undertaken at each site for a period of approximately 2-3 minutes, followed by an additional listening period of 5 minutes. Call playback is a method that is commonly used to invoke calling by non-calling nearby frogs. Call playback was not used at sites where GGF was heard calling nearby during the initial listening period. Call playback was not used in September, because the GGF was not a target species for that assessment.

- Scanning for eyeshine – after the initial listening period and call playback for GGF, the immediate areas was scanned for vertebrate eyeshine, and accessible eyeshine that could have been a frog was investigated. No other active searching was undertaken due to time constraints.

No dip netting for tadpoles was undertaken.

At all locations, all frog species heard were documented. An estimate was also made of the number of each frog species heard (i.e. minimum number of individuals known to be present), the direction that the frogs were thought to be, and the rough distance from the site to the frogs (acknowledging that distance estimates are fraught with error, particularly at night and with wind blowing).

Given the uncertainty in distance estimates, distance was recorded as a categorical variable: near (within 50 m or so of site location) or distant (more than 50 m from the site location).

Estimating frog abundance accurately in September 2017 was not possible due to the continuous distribution of large numbers of frogs across large expanses of wetland areas. Where very large numbers of frogs were heard, the estimate was capped at 30+, although there were likely to be far more frogs present than that.

Frog call identification was assisted by the use of pre-recorded frog calls using the app ‘Frogs of Australia – a complete electronic field guide to Australian frogs’ (Hoskin, C, Grigg, G, Stewart, D. & Macdonald, S. 2015).

All locations surveyed were recorded using a hand-held GPS unit (accuracy +/- 10 m) and later mapped using GIS. Field investigations were undertaken in accordance with GHD’s Wildlife Act 1975 Research Permit (#10007221) and GHD’s Standard Operating Procedures for the Animal Care and Ethics Committee.

Table 15 Amphibian Survey Locations

Survey point ID	Location description	Easting (55H)	Northing
1	Southern end of dirt track around lake, accessed from Fitzgerald Rd	275145	5766908
2	Boat ramp, through gate just east of end of Fitzgerald Rd	275336	5767311
3	Fitzgerald Rd (west end)	275807	5767897
4	Farm dam in private land (north side of road) across from locked gate on Fitzgerald Rd	275876	5767898
5	O’Halloran Rd (west end)	275891	5768694
6	Moolap Station Rd (southern end)	273793	5769206
7	Woods Rd (east end)	272998	5769017
8	Calder St (east end)	272433	5768558
9	Coppards Rd (southern end)	272063	5768222
10	South of Calder St. Through gate at end of Calder St, along grassy track south towards Barwon River	272238	5767934
11	Beside Barwon River, at stand of trees along grassy track	272008	5767122

Environmental conditions

The weather conditions during the nocturnal surveys (i.e., no daytime information included here) are outlined in

Table 16. The weather conditions on both December nights were suitable for frog surveys, being mild and relatively windless. The weather conditions in September were less ideal for frog surveys, being cool and breezy, but the survey was done immediately following a two-day warm period and large numbers of frogs were still detected.

Table 16 Weather conditions at start and finish of November / December frog surveys

	01/12/16		06/12/2016	
	Start	Finish	Start	Finish
Time	20:55	23:49	21:00	00:30
Temperature (wet bulb)	12°C	11°C	13.6°C	8.4°C
Humidity	77%	85%	78%	81%
Cloud cover	5%	10%	0%	0%
Precipitation	0	0	0	0
Wind	SE, breezy	none	none	none

6.4 Results

Five species of frogs were recorded at Reedy Lake:

4. Common Froglet, *Crinia signifera*;
5. Southern Brown Tree Frog, *Litoria ewingii*;
6. Growling Grass Frog, *Litoria raniformis*;
7. Southern Bull (Banjo) Frog, *Limnodynastes dumerili*; and
8. Spotted Marsh Frog, *Limnodynastes tasmaniensis*.

All five species were detected on both survey nights in December 2016. All December records of frogs are acoustic (heard) only – no frogs were seen during the assessment in December.

Three species were detected in September 2017 (not Growling Grass Frog or Southern Bull (Banjo) Frog). Individuals of all species were seen in September.

Table 17 outlines the frog species that were heard at the different sites, and an indication of minimum numbers heard. Results are presented for frogs heard 'near' and 'distant', in accordance with the description given in Sections below. For 'distant' frogs heard, an indication is given of the best estimate of direction of those frogs, made at the time of the assessment on the basis of landmarks and road directions (e.g., east-west, north-south).

6.4.1 December 2016

The Growling Grass Frog (*Litoria raniformis*) was the most ubiquitous species, being heard from 8 of the 11 sites (4 sites on the first night and 6 sites on the second night). All records of the GGF were of distant frogs, except for two: one male responded to call playback at the farm dam near the end of Fitzgerald Road (the dam is outside Reedy Lake itself), and three GGF were heard to the west of Coppards Road, but in the vicinity of the site.

GGF has a far-carrying call, and this is likely the reason so many individuals were heard at the sites. On this, it is difficult to determine how many GGF individuals were calling during the survey – at least 11 frogs were heard on night 1 and eight were heard on night 2. Historical VBA records of GGF suggested that the species only occupied habitats towards the eastern edge of the Lake (near the farm dam near the end of Fitzgerald Road). This assessment identified it is more widespread than that in the Reedy Lake system, and that its habitat also includes the western edge (near Coppards Road) and the lake itself (as heard from Woods Road), at least during the water conditions encountered at the time of survey.

Three species were equally common and ubiquitous, but less so than GGF: Common Froglet (*Crinia signifera*), Southern Brown Tree Frog (*Litoria ewingii*) and Spotted Marsh Frog (*Limnodynastes tasmaniensis*). These species are among the most common species in southern Victoria, and can adapt and persist in many habitat types. These species also tend to breed more in late winter and early spring after the winter rains, so it is not surprising that they were not recorded in large numbers.

One species was relatively uncommon in Reedy Lake at the time of the assessment Southern Bull (Banjo) Frog (*Limnodynastes dumerili*) (heard at/from three sites).

Call playback for GGF was successful at one site only. At the farm dam near the end of Fitzgerald Road, one GGF called in response to calls emitted from the loud speaker. That frog then hushed up and was not heard again at that site. Other GGF were heard later that night, calling without the stimulus of call playback.

6.4.2 September 2017

Three species were heard (Common Froglet (*Crinia signifera*), Southern Brown Tree Frog (*Litoria ewingii*) and Spotted Marsh Frog (*Limnodynastes dumerili*)); all were ubiquitous and all were heard in large numbers. These species are among the most common species in southern Victoria, and can adapt and persist in many habitat types.

The three species were heard at all sites visited, but the habitats they favoured appear to differ slightly. Two species heard (Common Froglet (*Crinia signifera*) and Spotted Marsh Frog (*Limnodynastes dumerili*)) were heard in very large numbers in the shallow flooded areas towards the margins of the lake. These areas are outside the area of deeper water and have shorter vegetation (<30 cm tall). These species were heard across very large expanses of that shallow wetland habitat, particularly towards the eastern side of the lake (Fitzgerald Road and O'Halloran Road). The distribution of these species appeared to be almost continuous in this habitat, although there were certainly areas where the frog choruses were particularly loud.

Foamy egg masses of Spotted Marsh Frog were seen at two sites (Fitzgerald Road and O'Halloran Road), but were probably present at all sites. These egg masses are likely to be the result of increased frog activity and breeding during the warmer nights that preceded the survey in September.

Southern Brown Tree Frog was heard mostly in the tall reeds/rushes (*Typha* and *Phragmites*) in the deeper, more central parts of the lake, although small numbers were also heard in surrounding fringing occasional wetland habitats outside the area of deeper water. It was present in large numbers, but assessing abundance was difficult because there were numerous frogs and their calls are heard over a long distance.

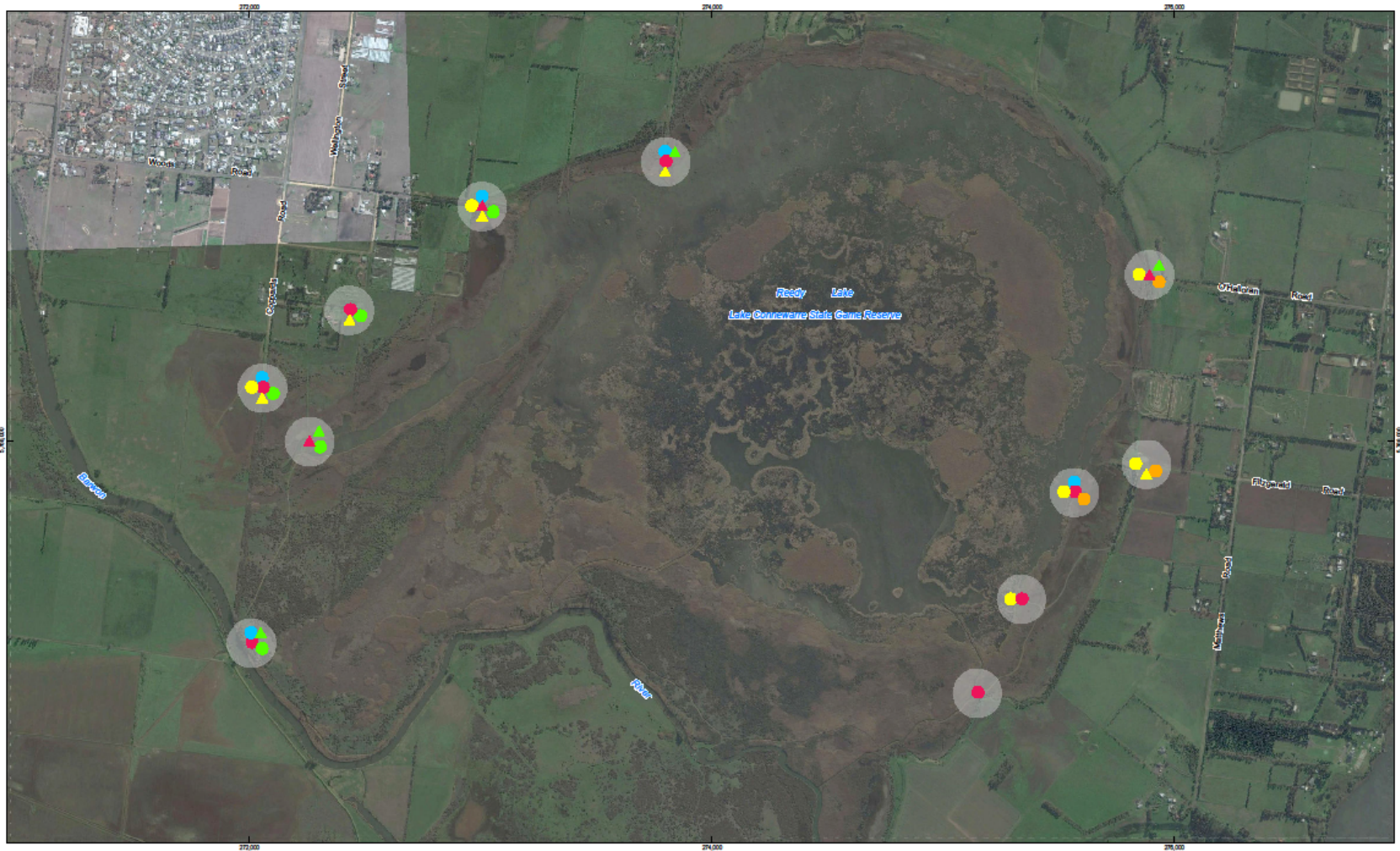
Table 17 Frog observations from the two nights of surveys

Abundance estimates where large numbers were heard are nominally capped at 30+.

Survey point ID	Location description	Date	<i>Crinia signifera</i>		<i>Litoria ewingii</i>		<i>Litoria raniformis</i>		<i>Limnodynastes dumerilii</i>		<i>Limnodynastes tasmaniensis</i>		Call Playback used?
			Near	Distant	Near	Distant	Near	Distant	Near	Distant	Near	Distant	
1	Southern end of dirt track around lake, accessed from Fitzgerald Rd	1/12/2016											Y
		6/12/2016			1								-
2	Boat ramp, through gate just east of end of Fitzgerald Rd	1/12/2016											Y
		6/12/2016			1			3 (to NE)					Y
		13/09/2017	30+	30+ (all directions)	5	30+ (to W)					30+ And Egg mass	30+ (all directions)	N
3	Fitzgerald Rd (west end)	1/12/2016	5		1								Y
		6/12/2016			1			1 (to E)	1				Y
		13/09/2017	30+	30+ (all directions)	5	30+ (to W)					10-20	30+ (all directions)	N
4	Farm dam in private land (north side of road) across from locked gate on Fitzgerald Rd	1/12/2016						1 (responded to CPB)					Y
		6/12/2016						1 (to W)	1				Y
		13/09/2017	10-20		2								N
5	O'Halloran Rd (west end)	1/12/2016		2 (to S)		1 (to S)				1 (to S)		3 (to S)	Y
		6/12/2016						1 (to S); 1 (to E)	1				Y
		13/09/2017	10-20	30+ (to W)	5	30+ (to W)					30+ And Egg mass	30+ (to W)	N
6	Moolap Station Rd (southern end)	1/12/2016	6			2 (to W)		1 (to SE)				Y	

Survey point ID	Location description	Date	<i>Crinia signifera</i>		<i>Litoria ewingii</i>		<i>Litoria raniformis</i>		<i>Limnodynastes dumerilii</i>		<i>Limnodynastes tasmaniensis</i>		Call Playback used?
			Near	Distant	Near	Distant	Near	Distant	Near	Distant	Near	Distant	
		6/12/2016						1 (to W)				2 (to NNW)	Y
		13/09/2017	10	30+ (to S, but all directions)	3	30+ (to S)					10	30+ (to S, but all directions)	N
7	Woods Rd (east end)	1/12/2016	3			1 (to SE)		2 (to SW, same as Coppards); 4 (to E), 300m+ away 3-4 (to SE), 200m+ away			1		Y
		6/12/2016											Y
		13/09/2017		30+ (to E and S)		10 (to S)						30+ (to S)	N
8	Calder St (east end)	1/12/2016						3 (to SW; same as Coppards)			4		Y
		6/12/2016			1			3 (to W, same as Coppards)			3		Y
9	Coppards Rd (southern end)	1/12/2016		3 (multiple directions)		1 (to W)		3 (to WNW)				10-20 (1 heard daytime also)	Y
		6/12/2016				1 (to NW)	3 (to W)				10 (to S)		Y
		13/09/2017			5	30+ (to S)						20 (to S)	N
10	South of Calder St. Through gate at end of Calder St, along grassy track south towards Barwon River	1/12/2016										chorus (at Coppards)	N
		6/12/2016		1 (to W)		3 (to W)					3		Y
11	Beside Barwon River, at stand of trees along grassy track	1/12/2016	1		1						3		Y
		6/12/2016										1 (to W)	Y

Survey point ID	Location description	Date	<i>Crinia signifera</i>		<i>Litoria ewingii</i>		<i>Litoria raniformis</i>		<i>Limnodynastes dumerilii</i>		<i>Limnodynastes tasmaniensis</i>		Call Playback used?
			Near	Distant	Near	Distant	Near	Distant	Near	Distant	Near	Distant	
Total	Numbers of locations heard	1/12/2016	4	2	2	4	1	4	0	1	4	2	
		6/12/2016	0	1	4	2	1	6	3	0	3	2	
		13/09/2017	5	5	6	6	-	-	-	-	4	6	
		combined	7	7	9	7	2	8	3	1	9	8	



<p>Paper Size A3</p> <p>0 75 150 300 450 600</p> <p>Metres</p> <p>Map Projection: Transverse Mercator Horizontal Datum: GDA 1984 GHD: GDA 1984 MGA Zone 55</p>		<p>LEGEND</p> <p>Frog Species by Proximity</p> <ul style="list-style-type: none"> ● Crinia signifera (Close) ● Crinia signifera (Distant) ● Limnodynastes dumerilii (Close) ● Limnodynastes dumerilii (Distant) ● Limnodynastes tasmaniensis (Close) ● Limnodynastes tasmaniensis (Distant) ● Litoria ewingii (Close) ● Litoria ewingii (Distant) 	<ul style="list-style-type: none"> ▲ Limnodynastes dumerilii (Distant) ▲ Limnodynastes tasmaniensis (Close) ▲ Limnodynastes tasmaniensis (Distant) ▲ Litoria ewingii (Close) ▲ Litoria ewingii (Distant) ▲ Litoria raniformis (Close) ▲ Litoria raniformis (Distant) 	<div style="border: 1px solid black; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center; margin: 5px auto;"> Client Logo </div>	<p>Client Name Project Name</p> <p>Figure Description1 Figure Description2</p>	<p>Job Number Revision Date</p> <p>31-34598 A 08 Dec 2016</p>
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6/13/16 09:00:00 MapView02134598_001_Progressions_A3.mxd
 © 2016. Whilst every care has been taken to prepare this map, GHD (and DATA CUSTODIAN) make no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damages) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unavailable in any way and for any reason.
 Data Source: Image © 2016 Google, DigitalGlobe dated 20160812 extracted 20161208. Created by smwh

6.5 Discussion of baseline data

The objective of this assessment was to provide baseline information on the frog fauna at Reedy Lake. The results of the December 2016 assessment have shown that there are at least 5 species of frogs at Reedy Lake, and surveys in September 2017 showed that, with suitable water levels and at a suitable time of year, the common species can be present in very large numbers indeed.

Two of the common species common eastern froglet (*Crinia signifera*) and spotted grass frog (*Limnodynastes tasmaniensis*) appear to favour habitats around the margins of the lake, when the water level is high enough to flood the low vegetation in those areas. When wet, those areas are likely to provide ideal habitats and conditions for breeding (eggs, tadpoles, metamorphosis). One common species southern brown tree frog (*Litoria ewingi*) appears to favour taller vegetated habitats within the deeper and more permanent parts of the lake, but it still uses areas with lower vegetation, in smaller numbers.

One uncommon species growling grass frog (*Litoria raniformis*) is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act (1999)* and appears to favour the deeper and more permanent parts of the lake. The GGF does not appear to be present in large numbers, compared with the other species. This is similar to the eastern banjo frog (*Limnodynastes dumerili*) which also appears to be fairly uncommon around the lake.

6.6 What do the results tell us about the 2016-17 wetting and drying regime?'

Frog monitoring has identified the five species identified during surveys have some differences in habitat preferences. Frog populations will respond to the wetting and drying regime in accordance with habitat availability as influenced by water levels.

- The eastern froglet (*Crinia signifera*) and spotted grass frog (*Limnodynastes tasmaniensis*) appear to favour habitats around the margins of the lake responding to higher water levels. At higher water levels the fringing saltmarsh vegetation is likely to provide ideal habitats and conditions for their life cycle.
- The southern brown tree frog (*Litoria ewingi*) appears to favour taller vegetated habitats within the deeper and more permanent parts of the lake where water levels are more persistent.
- The nationally listed growling grass frog (*Litoria raniformis*) and eastern banjo frog (*Limnodynastes dumerili*) are not present in large numbers around the lake. Both species favour deeper and more permanent parts of the lake.

6.7 Management considerations

The results of the December 2016 assessment have shown that there are at least five species of frogs at Reedy Lake. Surveys in September 2017 identified that, suitable water levels and at a suitable time of year, the common species can be present in very large numbers.

Timing of the implementation of a drying regime should where possible to commence after the breeding season for eastern froglet and spotted grass frog. High lake levels and wet years will support all frog species.

6.8 Recommendations for future monitoring

The surveys in December 2016 and September 2017 appear to be the first assessment of their kind to understand the frog fauna that inhabit Reedy Lake.

The results of these surveys provide a baseline for the presence of frogs and information collected should be further expanded in order to gather a more thorough data set on the presence of frogs. This will assist with understanding any potential impact associated with the altered environmental watering regime.

It is recommended that during the environmental watering regime, frog surveys are conducted biannually in Reedy Lake:

- In November/December to survey the Growling Grass Frog, and
- Again in late winter (July to September) to survey winter breeding species.

Surveys should be done at as many of the 11 locations as possible, recognising that actual sites assessed can vary with access and water level.

7. Vegetation monitoring

7.1 Scope

The botanical survey aims to establish a baseline for future monitoring of the response of vegetation to an altered drying regime. One purpose of the proposed drying regime is to preserve and enhance botanical values by promoting growth of small native herbs and sedges while constraining encroachment of dominant rushes and reeds. To establish a baseline and to evaluate likely current trends, the diversity and abundance of the lake's flora at the time the process of lowering the lake levels commenced in late 2016, were also compared with an earlier survey in late 2010/early 2011 (Ecological Associates 2012).

The botanical survey also aimed to evaluate current and potential threats that may arise as a consequence of environmental watering regime specified in *Seasonal Watering Proposal for the Lower Barwon Wetlands 2017 -18* (CCMA, 2017).

7.2 Historical context

The vegetation of Reedy Lake includes aquatic and semi-aquatic plant communities consisting of reedland, shrubland, grassland, sedgeland, saltmarsh and herbfield, described in a number of mapping, survey and monitoring projects over the last 30 years. Yugovic (1985) defined and mapped eight vegetation communities in 1983 which were revised by Sinclair (2010) to align with Victoria's system for describing vegetation according to Ecological Vegetation Classes (EVCs). Yugovic's mapping was also used by Ecological Associates (2012) as a basis to compare vegetation changes between 1983 and 2012. In this project, high resolution imagery and a quadrat-based field survey were used to produce a fine scale vegetation map representing 16 plant communities, as part of a project that mapped and described vegetation in the Lake Connewarre Complex (Lake Connewarre, Reedy Lake, Hospital Swamp, Salt Swamp, Lake Murtnaghurt and associated sections of the lower Barwon River) (Ecological Associates 2012, 2014).

Vegetation composition and distribution at Reedy Lake is broadly correlated with salinity, water depth and length of inundation, although this varies according to local topographic variation. Reedland dominated by *Phragmites australis* (Common Reed) or *Typha orientalis* (Broadleaf Cumbungi) occupies deeper water in permanently wet areas throughout the lake (other than in the Big Hole which), but can also occupy shallow water and damp soils. Of all the plant communities at Reedy Lake, reedland is most extensive and has doubled in area since 1983, covering over 400 ha in 2012 (Ecological Associates 2014).

The spatial area of other plant communities has also increased. *Bolboschoenus caldwellii* (Salt Club-rush) sedgeland occurs at the upper limit of the flood zone and almost doubled in extent between 1983 and 2012. It occupied roughly 107 ha of the lake area in 2012. *Duma florulenta* (Lignum) shrubland, distributed on higher ground in the most elevated sites, also became more extensive (50 ha to 105 ha) over the same period (Ecological Associates 2014).

Saltmarsh, which occurs in similar areas to sedgeland as well as at slightly higher elevations, declined by over 75% from 44 ha in 1983 to just 9 ha in 2012. *Distichlis distichophylla* (Emu-grass) grassland/shrubland, which also occurs above the flood zone, declined from 5 ha to 3 ha between 1983 and 2012. Vegetation dominated by exotic species also declined in extent from 90 ha to 11 ha and the area occupied by open water reduced by roughly one third between 1983 and 2012. These trends appear to be a result of reed encroachment (Ecological Associates 2014).

Recent work has focussed mainly on reed encroachment as a major threatening process since water levels in the lake have increased and been maintained over longer periods of time, with a concurrent drop in the influence of salinity from groundwater and estuarine sources (Alluvium 2103; Ecological Associates 2012, 2014). Removal of grazing may also explain the recent increase in reed extent (Alluvium 2103, Ecological Associates 2014).

Alluvium (2013) reviewed methods for control of *Phragmites* with respect to altered water regimes, tidal flushing, slashing, chemical and biological control. They concluded that the most appropriate control method that was compatible with the conservation, social and hydrological values of the lake and to prevent contamination from acid sulphate soil exposure, was a 1 in 4 year drying regime, together with regular slashing to further control *Phragmites* and *Typha* spread.

A monitoring program was established in January 2013 (for *Phragmites*) and extended in 2014 to include *Typha*. Data collected included stem (*Phragmites*) or ramet (*Typha*) density and height, and leaf numbers and dimensions (Ecological Associates 2014). *Phragmites* stem density and height was highest around the outlet but tended to be denser and shorter with increased salinity. Overall growth declined in 2014 compared to 2013. However, the most favourable conditions for *Phragmites* growth were found to be on fresh soils with shallow flooding and persistent waterlogging. These conditions allow development of robust plants with low stem densities which grow vigorously throughout summer and into autumn (Ecological Associates 2014).

Typha varied across the lake with respect to ramet height and density but only a single years' data have been collected to date and thus no trends have been detected.

There has been very little work that specifically addresses the botanical values of Reedy Lake, in spite of its rich flora (Yugovic 1985), high conservation value and diversity of vegetation (Ecological Associates 2012, 2014), including the presence of State and Federally listed threatened flora and vegetation communities. The most comprehensive vegetation survey was conducted by Ecological Associates (2012). They surveyed 102 quadrats across the entire lake system, including 40 quadrats at Reedy Lake, in areas roughly below 1.0 m AHD.

7.3 Monitoring program

7.3.1 Field survey

A subset of 24 (20 m x 20 m) quadrats (Plate 4) around the entire lake perimeter was selected from the original 40 quadrats surveyed by Ecological Associates in 2010/2011. Quadrats were chosen to represent the range of plant communities identified in the earlier survey. Quadrats were not permanently marked and were re-located using GPS, with an assumed accuracy of approximately 5m. The area proposed for drying was surveyed on 23 and 24 November 2016, a fortnight after the water level peaked at c. 1.25 m AHD. Water level height at the time of the survey was around 0.62 m AHD but had mostly been around 1 m AHD in the preceding four weeks. Typical lake levels are 0.7 AHD in winter/spring, drying to around 0.4 m AHD in late summer (Lloyd *et al.* 2012) but rarely exceed 0.9 AHD (Water Technology 2011). All vascular plants species were recorded and their percent cover estimated visually (to 5%). Water depth was also recorded in each quadrat.



Plate 4 Quadrat layout

7.3.2 Survey limitations

There were some constraints to comparing floristic quadrat data collected in 2010 with data from the current project. In the earlier survey, species cover was measured in Braun Blanquet cover-abundance classes. Although suitable as mapping units, these classes are too coarse to detect any change other than at relatively large scales, particularly at species level. Other common problems with comparing data sets are changes to nomenclature/taxonomy and mis-identifications, which make calculating specific indices, for example species diversity, inaccurate and potentially misleading.

7.3.3 Data analysis

To detect changes resulting from ecological processes following drying (including unexpected changes) we opted for an approach that could utilise the existing comprehensive dataset and provide a baseline to document trends in the floristic, structural and functional composition of vegetation.

To compare the proportion of small native herbs and sedges with other more dominant lifeforms, native species were allocated to broad structural groups. Structural groups were small herb or graminoid (SHG), medium graminoid (MG), woody perennial (WP) or dominant rush (DR) (Appendix 1).

To estimate likely change in vegetation composition and function, the entire floristic data set (natives and weeds) was allocated to Plant Functional Groups (PFGs; Casanova 2011, 2015) (Appendix 1). PFG categories are derived from a combination of morphological traits and ecological tolerances based on observations that growth and distribution of water plants are a response to water availability, flow, timing and depth (Casanova 2011). Thus, aquatic plants can be grouped according to their preferred water regime (Casanova 2011). PFGs are increasingly more widely used by ecologists to correlate species composition with environmental processes for a number of reasons.

PFGs are ecologically based, plants are readily categorised and they are a useful means of comparing datasets without influence from taxonomic changes that inevitably occur over time.

Definitions of PFGs cite Casanova (2011) and are described in **Error! Reference source not found.**

Where present, stem density (number of stems or ramets/m²) and height of *Typha/Phragmites* (cm) were also recorded; however, it was beyond the scope of the current project to re-sample *Phragmites* and *Typha* transects established by Ecological Associates (2014).

One photo point was established at the northwest corner of each quadrat, looking diagonally toward the opposite corner.

Botanical nomenclature follows the Flora of Victoria (Royal Botanic Gardens 2017).

A number of measures were calculated from the floristic data. These were overall species richness, lifeform richness and percent frequency of occurrence, functional group richness and percent frequency of occurrence, and the proportion of weeds to natives. Percent frequency of occurrence was calculated as the number of times a species (or PFG) was recorded in all quadrats, divided by the total number of species (or PFGs) recorded to give the relative frequency, multiplied by 100 to give percent frequency. In other words, the number of times a species was recorded compared to the total number of species recorded, expressed as a percentage.

Reed and rush stem density (stems/m²) and height in quadrats where *Phragmites* and *Typha* were recorded in 2016, were compared with data collected in similar areas of the lake in transects in 2013 by Ecological Associates (2014).

Data were stored and analysed and graphs generated using Microsoft Excel.

7.4 Results

7.4.1 Native species

In total, 34 native species were recorded in 2010 and 35 in 2016. Of the rush and reed species, in both years *Bolboschoenus caldwellii* (Salt Club-rush) was the most frequently recorded species as a proportion of the total number of species recorded. Its frequency of occurrence was 54% in 2010 but by 2016 had increased to 75%, with a mean cover of 32% (Table 18).

Phragmites had the highest cover of any species recorded in 2016 (42%). Its frequency of occurrence increased from 13% in 2010 to 25% in 2016. *Typha* frequency increased from 8% in 2010 to 17% in 2016 but its cover was low (Table 18).

Other notable increases in percent frequency of occurrence were woody perennial *Duma florulenta* (Lignum, 13% to 25%) and the small sedge *Isolepis cernua* (Nodding Club-rush, 13% to 21%) (Table 18).

Notable declines in frequency of occurrence between 2010 to 2016 were herbs *Crassula helmsii* (Swamp Crassula, 23% to 12%), *Sarcocornia quinqueflora* (Beaded Samphire, 21% to 8%), *Senecio pinnatifolius* (Variable Groundsel, 21% to 13%) and the macro-algae *Chara* sp. (13% to 4%) (Table 18, Plate 5).



Plate 5 Saltmarsh community dominated by *Tecticornia pergranulata* (Black-seed Samphire) and *Cotula coronopifolia*

Table 18 Percent frequency of occurrence of native species in quadrats in 2010 and 2016 and mean percent cover of native species in 2016.

Species 2010	Frequency of occurrence (%) 2010	Species 2016	Frequency of occurrence (%) 2016	Mean % cover 2016
<i>Azolla rubra</i>	13			
<i>Bolboschoenus caldwellii</i>	54	<i>Bolboschoenus caldwellii</i>	75	32
<i>Calystegia sepium</i>	13	<i>Calystegia sepium</i>	17	5
<i>Chara sp.</i>	13	<i>Chara sp.</i>	4	0.01
<i>Crassula helmsii</i>	23	<i>Crassula helmsii</i>	12	1.1
<i>Distichlis distichophylla</i>	13	<i>Distichlis distichophylla</i>	13	78
<i>Duma florulenta</i>	13	<i>Duma florulenta</i>	25	26
<i>Eleocharis acuta</i>	25	<i>Eleocharis acuta</i>	17	0.3
<i>Eleocharis sphacelata</i>	4	<i>Eleocharis sphacelata</i>	4	15
<i>Epilobium billardierianum</i>	4	<i>Epilobium billardierianum</i>	4	0.02
<i>Frankenia pauciflora var. gunnii</i>	4	<i>Frankenia pauciflora var. gunnii</i>	4	0.01
		<i>Hydrocotyle sp.</i>	4	0.02
<i>Isolepis cernua</i>	13	<i>Isolepis cernua</i>	21	0.6
<i>Juncus procerus</i>	8	<i>Juncus procerus</i>	17	3.8
		<i>Juncus sp.</i>	4	0.5
<i>Lachnagrostis filiformis</i>	8	<i>Lachnagrostis filiformis</i>	4	0.01
<i>Lemna disperma</i>	17	<i>Lemna disperma</i>	13	0.03
		<i>Lemna sp.</i>	4	0.1
		<i>Lemna trisulca</i>	8	0.01
		<i>Lycopus australis</i>	4	0.01

Species 2010	Frequency of occurrence (%) 2010	Species 2016	Frequency of occurrence (%) 2016	Mean % cover 2016
		<i>Lythrum hyssopifolia</i>	4	0.2
<i>Lepilaena cylindrocarpa</i>	8			
<i>Lilaeopsis polyantha</i>	4			
<i>Lythrum hyssopifolia</i>	4			
<i>Melaleuca brevifolia</i>	4			
<i>Myriophyllum salsugineum</i>	13	<i>Myriophyllum salsugineum</i>	13	0.02
<i>Ornduffia reniformis</i>	13			
<i>Phragmites australis</i>	13	<i>Phragmites australis</i>	25	42
<i>Poa poiformis</i> var. <i>poiformis</i>	4	<i>Poa poiformis</i> var. <i>poiformis</i>	4	0.02
		<i>Poaceae</i> spp.	12	0.02
		<i>Potamogeton crispus</i>	13	0.3
		<i>Potamogeton</i> sp.	4	0.3
<i>Ranunculus amphitrichus</i>	8	<i>Ranunculus amphitrichus</i>	13	0.08
<i>Rumex bidens</i>	4			
<i>Sarcocornia quinqueflora</i>	21	<i>Sarcocornia quinqueflora</i>	8	34
<i>Schoenoplectus tabernaemontani</i>	4			
<i>Senecio pinnatifolius</i>	21	<i>Senecio pinnatifolius</i>	13	0.08
<i>Spergularia tasmanica</i>	4			
<i>Stuckenia pectinata</i>	13	<i>Stuckenia pectinata</i>	17	0.5
<i>Tecticornia pergranulata</i>	13	<i>Tecticornia pergranulata</i>	17	27
		<i>Thyridia repens</i>	17	2.5
<i>Triglochin procerum</i>	8	<i>Triglochin procerum</i>	17	1
<i>Triglochin striatum</i>	8	<i>Triglochin striatum</i>	4	2
<i>Typha orientalis</i>	8	<i>Typha orientalis</i>	17	3

Note: Green, > 20% increase in percent frequency of occurrence; red, >20% decline percent frequency of occurrence.

Cover was measured in Braun-Blanquet units in 2010 and is not included. Mean cover in 2016 is taken from quadrats where each species was recorded. Green, > 20% increase in percent frequency of occurrence; red, >20% decline percent frequency of occurrence.

The average number of species recorded per quadrat (mean species richness) and percent frequency of occurrence of native species recorded was more or less equivalent in 2010 and 2016 (Table 19).

Table 19. Mean species richness, frequency of occurrence and ratio of natives to weeds in 2010 and 2016.

Year	Mean species richness	Mean native species richness	Proportion of native species	Mean weed species richness	Proportion of weed species
2010	5.29	4	76%	1.29	24%
2016	5.79	4.5	78%	1.25	22%

7.4.2 Weeds

Fifteen weeds were recorded in 2010 and 10 in 2016 (Table 20). Mean weed species richness remained more or less consistent in each of the survey years but there were some noticeable changes in percent frequency of occurrence (Table 19).

The most commonly recorded weeds in 2010 were *Paspalum distichum* (Water Couch) and *Cotula coronopifolia* (Water Buttons). By 2016, Water Couch had declined (25% cf. 8% frequency) and Water Buttons had increased (17% cf. 33% frequency). Frequency of *Rumex crispus* (Curled Dock) increased significantly from 4% to 29%. *Polypogon monspeliensis* (Annual Beard-grass) and *Lolium hybridum* (Ryegrass) percent frequency declined between 2010 and 2016.

Most other weed species' cover was low (Table 20). Otherwise, more or less the same suite of introduced species was recorded in each of the survey years in roughly similar frequencies. Weed species that were absent from quadrats in 2016 were *Cirsium vulgare* (Spear Thistle), *Carduus tenuiflorus* (Slender Thistle), *Sonchus oleraceus* (Common Sow-thistle), *Erigeron sumatrensis* (Tall Fleabane) and *Symphotrichum subulatum* (Aster-weed) although these were infrequent in 2010.

Table 20 Percent frequency of occurrence of weed species in 2010 and 2016 and mean weed cover in 2016.

Species 2010	Frequency of occurrence (%) 2010	Species 2016	Frequency of occurrence (%) 2016	Mean % cover 2016
<i>Symphotrichum subulatum</i>	4			
<i>Atriplex prostrata</i>	4	<i>Atriplex prostrata</i>	17	<1
<i>Carduus tenuiflorus</i>	4			
<i>Cirsium vulgare</i>	4			
<i>Cotula coronopifolia</i>	17	<i>Cotula coronopifolia</i>	33	7.5
<i>Erigeron sumatrensis</i>	4			
<i>Hordeum marinum</i>	8	<i>Hordeum marinum</i>	13	1
<i>Lolium hybridum</i>	8	<i>Lolium hybridum</i>	4	2
<i>Lolium multiflorum x rigidum</i>	4	<i>Lolium multiflorum x rigidum</i>	4	<1
<i>Lolium rigidum</i>	4			
<i>Paspalum distichum</i>	25	<i>Paspalum distichum</i>	8	4
		<i>Phalaris aquatica</i>	4	<1
<i>Polypogon monspeliensis</i>	13	<i>Polypogon monspeliensis</i>	4	3
<i>Rumex conglomeratus</i>	17	<i>Rumex conglomeratus</i>	13	5
<i>Rumex crispus</i>	4	<i>Rumex crispus</i>	29	<1
<i>Sonchus oleraceus</i>	8			

Cover was measured in Braun-Blanquet units in 2010 and is not included. Mean cover in 2016 is taken from quadrats where each species was recorded. Green, > 20% increase in percent frequency of occurrence; red, >20% decline percent frequency of occurrence.

7.4.3 Native species structural groups

Small native herbs and graminoids were the most frequently recorded in both survey years (Figure 14). Examples of the most common species in both years were *Calystegia sepium*

(Large Bindweed), *Eleocharis acuta* (Common Spike-rush), *Stuckenia pectinata* (Fennel Pondweed), *Myriophyllum salsgineum* (Lake Water-milfoil) and *Isolepis cernua* (Nodding Club-rush). Not or seldom recorded in 2016 were *Azolla rubra* (Pacific Azolla), *Lemna disperma* (Common Duckweed) and *Ornduffia reniformis* (Running Marsh-flower). These species were recorded in frequencies of 13 – 17% in 2010.

Medium graminoids increased slightly overall (Figure 13), due to an increase in Salt Club-rush but other species were relatively infrequent in each of the survey years. Species in this group also included *Eleocharis sphacelata* (Common Spike-rush), *Schoenoplectus tabernaemontani* (River Club-sedge), *Poa poiformis* var. *poiformis* (Coast Tussock-grass) and *Juncus procerus* (Tall Rush).

Woody perennials were rarely recorded (Figure 14), and other than an increase in *Duma florulenta* (Lignum), there was little or no change in other woody species *Tecticornia pergranulata* (Black-seed Samphire) and *Frankenia pauciflora* (Southern Sea-heath).

The frequency of occurrence of dominant rushes and reeds increased in 2016 (Figure 14), owing to an increase in the frequency of *Phragmites* and to a lesser extent *Typha*.

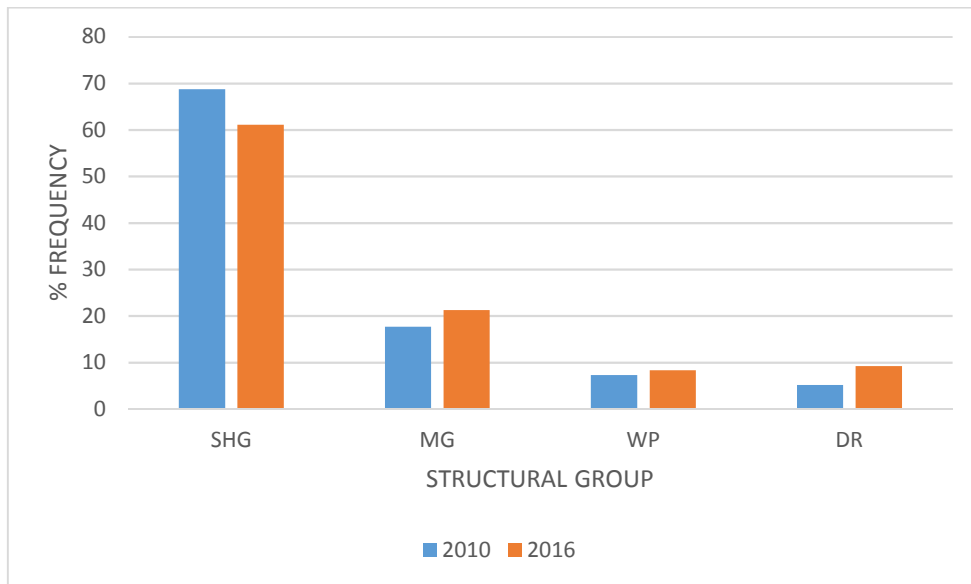


Figure 14 Percent frequency of occurrence of native species structural groups

SHG, small herb or graminoid; **MG**, medium graminoid; **WP**, woody perennial; **DR**, dominant rush.

7.4.4 Plant Functional Group richness and frequency of occurrence

A comparison of the mean species richness of each PFG between 2010 and 2016 showed that there was little difference, other than some minor changes (Figure 14). This is because the quadrats were very species poor overall and any change in mean species richness was of low magnitude, in the order of only 1 or 2 species. Differences are better illustrated by percent frequency of occurrence of PFGs (Figure 15).

There was an increase in woody and monocotyledonous perennial emergents (**Se** species) that require permanent water in the root zone, but remain emergent. They thrive where water levels do not fluctuate or fluctuate little and at Reedy Lake are represented by *Typha*, Water Ribbons (*Triglochin* spp.) and Salt Club-rush.

In 2016, there was also some increase in terrestrial damp species (**Tda** species) that germinate and establish on saturated or damp ground, but cannot tolerate flooding in the vegetative state.

These include weed species *Atriplex prostrata* (Creeping Saltbush) and *Rumex* spp. (Docks), as well as natives such as *Frankenia pauciflora* (Southern Sea-heath), *Juncus* spp. (Rushes) and *Poa poiformis* (Coast Tussock-grass).

Over the same period, there was a decrease in terrestrial dry species (**Tdr** species) that do not require flooding and will persist in damper parts of the landscape. Examples are natives *Calystegia sepium* (Large Bindweed), *Senecio pinnatifolius* (Variable Groundsel) and weeds *Hordeum marinum* (Sea Barley-grass), *Lolium* spp. (Ryegrass) and *Phalaris aquatica* (Toowoomba Canary-grass).

There was also a small decrease in species that respond to fluctuating water levels (ARf, Ate species). An increase was also evident in similar species – plastic amphibious fluctuation responders (**Arp** species) and low growing fluctuation tolerators (Ate species); however, this increase was mainly attributable to the weed *Cotula coronopifolia* (Water Buttons).

Emergent amphibious fluctuation tolerators (**ATe** species) decreased slightly in 2016. These consist of monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water. At Reedy Lake, these species include *Phragmites*, which was more frequent overall; however, this group also includes a range of smaller species such as *Sarcocornia quinqueflora* (Beaded Samphire), *Lycopus australis* (Australian Gipsywort), *Eleocharis* spp. (Spike-rushes), *Tecticornia pergranulata* (Black-seed Samphire) and *Lachnagrostis filiformis* (Perennial Blown-grass). Beaded Samphire and to a lesser extent Common Spike-rush, declined significantly between 2010 and 2016 (Table 18).

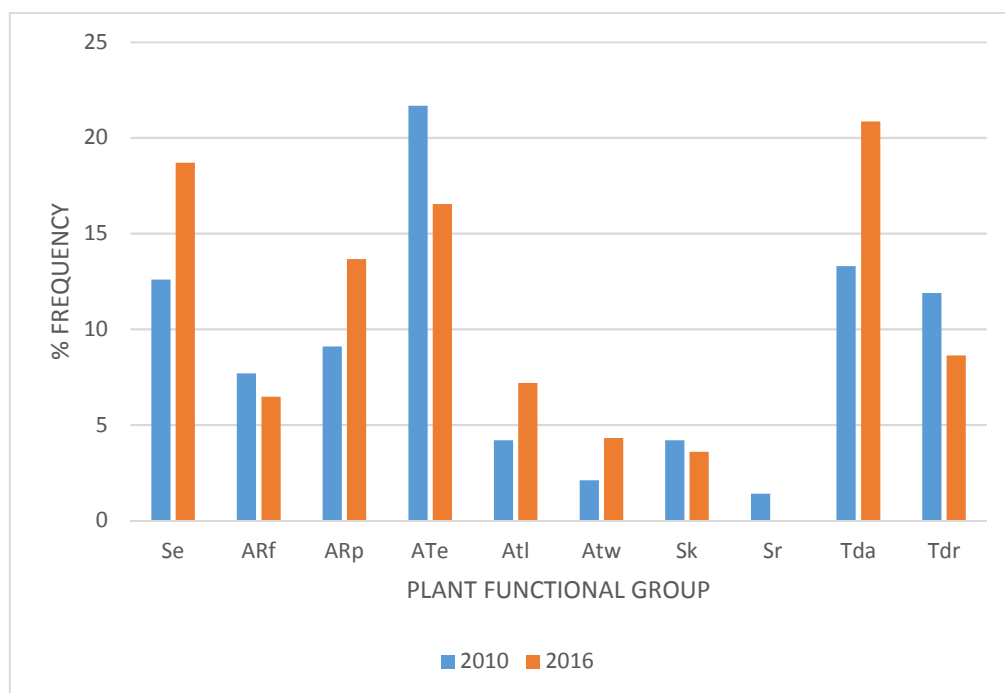


Figure 15 Plant Functional Group species frequency of occurrence in quadrats in 2010 and 2016

Se, Perennial – emergent; ARf, Amphibious fluctuation responder – floating; ARp, Amphibious fluctuation responder – plastic; Ate, Amphibious fluctuation tolerator – emergent; ATL, Amphibious fluctuation tolerator – low-growing; ATw, Amphibious fluctuation tolerator – woody; Sk, Submerged – k-selected; Sr, Submerged – r-selected. Tda, Terrestrial damp; Tdr, Terrestrial dry.

7.4.5 Phragmites and Typha abundance

There was only limited opportunity to compare stem/ramet density and height between the two survey years, since *Phragmites* and *Typha* occurred in only four and two quadrats, respectively, close to the outlet pipe (Table 21, Table 22).

Phragmites stem density and height decreased from 2010 to 2016. Dead stems were not counted in 2010 but there appeared to be high mortality, which may partially explain the results (Plate 16). However, the small number of quadrats sampled means that these results have only limited usefulness (Table 21).

Table 21 *Phragmites* mean live stem density 2013 and 2016; mean dead stem density and mean stem height 2016.

2010 data are taken from Ecological Associates (2014). NR, not recorded.

Year	Site	Elevation	Mean live stem density/m ²	Mean dead stem density/m ²	Mean stem height (cm)
2013	North and east edge n= 7 transects	0.6 -0.7	71.9	NR	196
2016	n= 2 quadrats, 33, 43		51.6	120	110
2013	North and east deep n= 9 transects	0.3, 0.4	50.2	NR	213
2016	n= 1 quadrat (42)		12.5	2.5	130
2013	Levee near outlet N=2 transects)	0.9	70	NR	316
2016	n= 1 quadrat (38A)		60	200	160



Plate 16 Dead *Typha* stems.

Typha ramet density appeared to decline dramatically but there were too few quadrats sampled to draw any firm conclusions (Table 22).

Table 22 *Typha* mean live stem density 2014 and 2016; mean dead stem density and mean stem height 2016.

2010 data are taken from Ecological Associates (2014). NR, not recorded.

Year	Site	Elevation		Mean live ramet density/m ² Quad 41, 42	Mean dead ramet density/m ² Quad 41, 42	Mean ramet height (cm)
2014(n=1 transect)	Northeast near O'Halloran Rd n=1 transect	0.4	103.1	N/R	N/R	
2016	n=2 quadrats, 41 and 42	0.4	0.32	225	110	

7.5 Discussion of baseline data

7.5.1 New and emerging threats

There is a substantial body of information with respect to reed encroachment dynamics in response to the full water level regime that has been in place over the last decade at Reedy Lake. This project aimed to identify new and emerging threats, to evaluate their predicted impact, and the impact of existing threats on habitat diversity and condition in response to the drying regime, including reed encroachment in and near the outlet channel.

The *Phragmites* and *Typha* monitoring transects established in 2013/2014 were not re-measured as part of the current project. However, a limited amount of quadrat data indicates that some trends which may have occurred since 2010 include further spread of reeds and rushes. These trends are consistent with observations in earlier studies (Alluvium 2013, Ecological Associates 2012, 2014). Also of note was a possible increase in Salt Club-rush, as well as the large shrub Lignum. Anecdotal information from CCMA since surveys were

completed indicate there may have been a decrease in reeds and rushes following the drying regime. The *Phragmites* and *Typha* monitoring transects established in 2013/2014 would need to be revisited to qualify any changes.

Phragmites stems measured in a quadrat near the outlet channel were less dense and were also shorter than in 2013. A large number of dead stems was also recorded. The results from this very limited amount of data broadly indicate that *Phragmites* may have declined slightly in this area of the lake. However, re-monitoring the established *Phragmites* and *Typha* transects is necessary to detect any trends that may be occurring. Since reed and rush encroachment has been identified as a key threat to ecosystem function, and the drying regime is likely to influence their spread (Alluvium 2013, Ecological Associates 2014), re-measuring these transects should be undertaken as soon as possible, since relatively little time has elapsed since water lowering commenced and the results will inform future implementation of the regime.

Spread of Salt Club-rush was also noted as of concern by Ecological Associates (2012), who measured an increase in its extent, most likely caused by removal of grazing. However, a combination of lack of grazing combined with increased habitat availability (i.e. extended inundated areas) may also promote its spread.

A concurrent decline in saltmarsh vegetation observed in the same study (Ecological Associates 2012) is attributed to competition from Salt Club-rush spread and from exotic grasses. Similar trends were indicated in the current study (e.g. Figure 16). Mean cover of Salt Club-rush (32%) was above the benchmark for Brackish Wetland Aggregate (EVC 656) of 10-20%, suggesting that it is outcompeting associated species in the same EVC. A decline in the frequency of occurrence of saltmarsh species Beaded Samphire and Swamp Crassula was also recorded. This may be a consequence of consistently elevated water levels, rather than fluctuating levels, characteristic of fringing saltmarsh habitat. Spread of water Buttons is also of particular interest since this species has increased dramatically since higher water levels have been maintained. The impact of Water Buttons encroachment on indigenous saltmarsh species is poorly understood at present and has not been recorded elsewhere. Given its ability to form extensive mats and tolerate a wide range of moisture levels and salinities, its rapid spread may be a consequence of increased habitat availability. Larger saltmarsh species Black-seed Samphire and Southern Sea-heath remained stable. Causes of these trends, if they persist, may become more apparent in future once the monitoring program progresses throughout a number of wetting/drying regimes.



Figure 17 Brackish Wetland Aggregate dominated by Salt Club-rush

This vegetation community is referable to *Bolboschoenus caldwellii* Sedgeland (Ecological Associates 2012).

Lignum is able to tolerate a wide range of soil moisture conditions but growth and recruitment may be constrained in the very wettest areas. Lignum is a woody perennial that is able to recruit on a drying profile or in shallow water (amphibious fluctuation tolerator) but expands after flooding. The altered drying regime may also promote its spread. Mean Lignum cover was 26% (Figure 17), well above the benchmark for Brackish Lignum Swamp (EVC 947) of 10% (DELWP 2016) and control may be necessary in future to limit competitive effects and maintain species richness in this EVC.



Figure 18 Brackish Lignum Swamp dominated by *Duma florulenta* (Lignum) and *Distichlis distichophylla* (Emu-grass).

This vegetation community is referable to *Muehlenbeckia florulenta* Shrubland over *Distichlis distichophylla* (Ecological Associates 2012).

Weed cover was generally relatively low but Water Buttons and Curled Dock occurred frequently throughout quadrats. The former species may pose a significant threat to saltmarsh

vegetation in fringing saltmarsh vegetation (Plate 19). Low cover of other weeds may be a consequence of recently high water levels suppressing growth but their current frequency of occurrence also suggests that once more damp/dry ground is available for colonisation then these are likely to spread.



Plate 19 *Cotula coronopifolia* (Water Buttons), dominating saltmarsh vegetation.

7.5.1 Vegetation and water regime

The overall objective of the planned drying regime is to restore ecological values by returning the lake to a more natural drying cycle. The botanical component of the current project established a baseline inventory of floristic composition and compared the results with those from an earlier survey in 2010. During this period, lake levels had been artificially maintained at high levels during summer, in contrast to the planned regime of lowering water levels to below 0.3 m AHD as part of a 1 in 4 year program. In future, floristic monitoring data will be used to evaluate the likely effectiveness of periodic drying on habitat values and floristic diversity with respect to water quality, water residency time, salinity and other hydrological variables.

There were some signs of a decline in frequency (c. 10%) of small herbs and graminoids but it was not possible to compare their cover over the same period (see methods, above). Overall species composition was broadly similar but since the exact location of quadrats was not marked and given the error margin of GPS accuracy, some floristic variation was expected. A small increase in the frequency of occurrence of medium graminoids, woody perennials (Lignum) and dominant rushes also suggests some change has occurred since water levels have been high. However, some species that were absent or only infrequently recorded in 2016 included submerged, aquatic or semi-aquatic herbs, suggesting that other factors (e.g. carp, salinity) may be responsible for their decline, or extended periods of dry weather during cooler autumn months in previous years may have impacted their growth. Further work is needed to evaluate these impacts and to clarify any apparent trends.

There was little significant change in the frequency of occurrence of Plant functional Groups (PFGs) between 2010 and 2016. The largest change was an increase (c. 7%) in terrestrial dry species (Tdr species) that do not tolerate flooding. This group included weeds and natives that were generally recorded in quadrats in more elevated areas, with the exception of the robust native graminoid Tall Rush (*Juncus procerus*). Since these areas are likely to have avoided high water levels for much of the time since 2010, their increase in frequency and spread may be a result of unseasonal drier weather throughout the last few years.

7.6 What do the results tell us about the 2016-17 wetting and drying regime?

Vegetation monitoring has provided a baseline of the current distribution and abundance of plant functional groups and indicator species. Since previous monitoring in 2013/14 the current program identified relatively minor changes in most species and their distribution and those of plant functional groups.

As there has been no drying period since the previous monitoring in 2013/2014 species functional groups are not expected to have changed considerably

While the *Phragmites* and *Typha* monitoring transects established in 2013/2014 were not re-measured as part of the current project some of the quadrat data indicate further spread of reeds and rushes.

Anecdotal information from CCMA since surveys were completed indicate there may have been a decrease in reeds and rushes following the drying regime. The *Phragmites* and *Typha* monitoring transects established in 2013/2014 would need to be revisited to qualify any changes.

However, some trends require further consideration. These include an inferred decrease in species that respond to fluctuating water levels, and an increase in species that tend to tolerate, or are opportunistic of, water level fluctuations such as the sedge, Salt Club-rush. Interestingly, these trends were predicted to occur by Ecological Associates (2012).

7.7 Management considerations

The current monitoring program has established a baseline at the commencement of the drawdown of the lake for the drying period. The impact and benefits of the drying regime can only be assessed through implementation of the monitoring program in future.

Vegetation monitoring results indicate that consistently elevated water levels in Reedy Lake have continued to influence vegetation quality, function and extent, favouring deeper water species (native and exotic), disadvantaging other native species that respond to water fluctuations and encouraging the spread of weeds.

7.8 Recommendations for future monitoring

The current survey established a basis for future monitoring of the floristic composition, and structure and function of vegetation at Reedy Lake. Comparison to the earlier data set was still useful, even though the two studies used different methods to measure cover, since the vegetation could still be compared on the basis of its functional and structural composition.

It should be noted that this study collected baseline data, at the time of water lowering and compares the results to an earlier study conducted under similar water level conditions. It is important to understand that changes in vegetation composition and species abundance can only be evaluated with ongoing monitoring throughout a series of wetting/drying regimes. Plant populations take time to adjust to new conditions and responds to management intervention. At present, no firm conclusions can be drawn on population responses to wetting/drying cycles for any of the species at Reedy Lake. However, some trends were detected over the period that water levels had been retained at artificially high levels.

Specific areas of concern were a substantial decline in fringing saltmarsh species Beaded Samphire, a likely decline in small herbs and sedges, and an increase in the extent of *Phragmites*, Salt Club-rush and Lignum since 2010. Saltmarsh is listed under the EPBC Act as a nationally threatened ecological community (Subtropical and Temperate Coastal Saltmarsh) and is of extremely high conservation significance.

The results also suggested that changes detected in 2016 may have been prompted by a combination of environmental conditions, including extended dry weather in earlier years, combined with elevated lake levels in recent summers. These conditions have favoured an increase in *Phragmites*, Lignum and terrestrial damp species able to colonise a wide range of soil moisture levels.

The results suggest that low water levels that extend into cooler months may promote weed establishment, especially flood-intolerant species. However, this requires further investigation.

Overall weediness remained more or less stable over the last few years. Extended periods of high water levels in 2016 may have suppressed spread of flood-intolerant weeds, at least to some extent. Periods of low water levels also provide a very good opportunity to control invasive species.

During the environmental watering regime, as outlined in CCMA (2017), recommendations include:

- Re-monitor established *Phragmites* and *Typha* transects by early 2017, using the approach recommended by Ecological Associates (2014).
- Permanently mark and re-survey 24 quadrats by January 2018.
- The existing vegetation mapping is relatively current (2014). However, as part of a long-term strategy, we propose that vegetation mapping is undertaken again within the next couple of years to evaluate trends, and compared to any future monitoring results.

- Regularly inspect the site and control weeds using methods compatible with the Reedy Lake's conservation values as a Ramsar site.
- Implement recommendations to trial mechanical control of *Phragmites* and *Typha* (Alluvium 2013).
- Conduct a soil conductivity survey as recommended by Ecological Associates (2014) to inform management options for reed encroachment.

8. Recommended Monitoring Program

Future monitoring of the environmental values of Reedy Lake is an important aspect of the environmental watering regime outlined in the Proposal. In most instances, impact to the ecological values such as birds, frog, fish and vegetation will not be observed in the short term. Gathering a baseline data set during each watering regime proposed in the four years will provide a sound understanding of the impacts to Reedy Lake.

The following table presents the recommended monitoring program that should be implemented during the four year water cycle regime outlined in the *Seasonal Watering Proposal for the Lower Barwon Wetlands 2017 -18* (CCMA, 2017).

Watering Regime	Environmental Value	Monitoring Action	Location	Frequency
Low-partial drying (>0.0 m AHD)	Surface water	Telemetry meter measurements for water level, DO, EC and pH	Big Hole	Continuous
		<i>In situ</i> measurements	WQ_Inlet, WQ1, WQ2, WQ3, WQ4, WQM and WQ_Outlet	Prior to and at the maximum extent of the watering regime
	Sediment	Laboratory analysis of cores extracted to 30 cm	S1, S7 and S8	At the maximum extent of the watering regime
	Groundwater	Laboratory analysis	UB_FG1, UB_CS1 and UB_WH1	At the maximum extent of the watering regime
	Fish	Fish survey	Big Hole, inundated littoral area and outlet	At the maximum extent of the watering regime
	Fish (carp)	Fish Survey	Big Hole, inlet channel, outlet channel	Once water levels <0.02m AHD. Identify locations for removal
	Birds	Field surveys	Five land-based locations (Moolap Station Rd, Woods Rd, Coppards Rd, Fitzgerald Rd, O'Halloran Rd)	Late spring-early summer and late autumn-early winter
	Amphibians	Field surveys	Eleven locations, as described in Table 15	Late spring-early summer and late winter
	Vegetation	Field surveys	Twenty four vegetation quadrats Established <i>Phragmites</i>	January

Watering Regime	Environmental Value	Monitoring Action	Location	Frequency
			and <i>Typha</i> transects	
Partial drying (approximately 0.3 m AHD)	Surface water	Telemetry meter measurements for water level, DO, EC and pH	Big Hole	Continuous
	Sediment	Laboratory analysis of cores extracted to 30 cm	S7	At the maximum extent of the watering regime
	Groundwater	Laboratory analysis	UB_FG1, UB_CS1 and UB_WH1	At the maximum extent of the watering regime
	Fish	Fish survey	Big Hole, inundated littoral area and outlet	At the maximum extent of the watering regime. Review location of carp for potential eradication.
	Birds	Field surveys	Five land-based locations (Moolap Station Rd, Woods Rd, Coppards Rd, Fitzgerald Rd, O'Halloran Rd)	Late spring-early summer and late autumn-early winter
	Amphibians	Field surveys	Eleven locations, as described in Table 15	Late spring-early summer and late winter
	Vegetation	Field surveys	Twenty four quadrats	January
Full water year	Surface water	Telemetry meter measurements for water level, DO, EC and pH	Big Hole	Continuous
	Sediment	Not required		
	Groundwater	Not required		
	Fish	Not required		
	Birds	Field surveys	Five land-based locations (Moolap Station Rd, Woods Rd, Coppards Rd, Fitzgerald Rd, O'Halloran Rd)	Late spring-early summer and late autumn-early winter
	Amphibians	Field surveys	Eleven locations, as described in Table 15	Late spring-early summer and late winter
	Vegetation	Field surveys	Twenty four quadrats	January

9. Limitations

This report: has been prepared by GHD Pty Ltd (GHD) for Corangamite Catchment Management Authority (CCMA) and may only be used and relied on by Corangamite Catchment Management Authority for the purpose agreed between GHD and the Corangamite Catchment Management Authority as set out in Section 1 of this report. GHD otherwise disclaims responsibility to any person other than Corangamite Catchment Management Authority arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report. The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Corangamite Catchment Management Authority and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points. Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report. Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

10. References

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Appendices

Appendix A – Surface water, sediment and groundwater monitoring



CHAIN OF CUSTODY

ALS Laboratory:
please tick →

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Ph: 07 3243 7222 E: samples.librisbane@alsglobal.com
GLADSTONE 48 Callenmore Drive Clinton QLD 4680
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UPERTH 101 Hedley Way Maragee WA 6000
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LWOLONGONG 06 Komry Street Wollongong NSW 2500
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CLIENT: GHD

OFFICE: 180 Lonsdale Street Melbourne

ORDER NUMBER:
Reedy Lake 3134598

PROJECT MANAGER: Peter Lind

SAMPLER: Peter Lind

CONTACT PH: 0403 835 098

SAMPLER MOBILE: 0403 835 098

EDD FORMAT (or default):

Email Reports to (will default to PM if no other addresses are listed):

Email Invoice to (will default to PM if no other addresses are listed):

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

TURNAROUND REQUIREMENTS : Standard TAT (List due date):

(Standard TAT may be longer for some tests e.g. Ultra Trace Organics)

ALS QUOTE NO.:

FOR LABORATORY USE ONLY (GHD)

Customer Details
Residence
Workplace
School
Other

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 5 6 7

OF: 1 2 3 4 5 6 7

RECEIVED BY:

DATE/TIME:

RELINQUISHED BY:

DATE/TIME:

RECEIVED BY:

DATE/TIME:

RELINQUISHED BY:

DATE/TIME:

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).

ANIONS

CATIONS

DISSOLVED ORGANIC CARBON

TOTAL ORGANIC CARBON

DISSOLVED METALS

COMMENTS ON LIKELY CONTAMINANT LEVELS, DILUTIONS, OR SAMPLES REQUIRING SPECIFIC QC ANALYSIS ETC.

ADDITIONAL INFORMATION

Environmental Division
Melbourne
Work Order Reference
EM1702319

Telephone : + 61-3-9549 9600

Barcode

TOTAL

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cc Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic

V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl Preserved Plastic; HS = HCl Preserved Plastic; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;

Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottle; ASS = Plastic Bag for Acid Sulphate Solids; B = Unpreserved Bag.

CERTIFICATE OF ANALYSIS

Work Order : **EM1702319**
Client : **GHD PTY LTD**
Contact : **MR PETER LIND**
Address : **LEVEL 8, 180 LONSDALE ST**
MELBOURNE VIC, AUSTRALIA 3001
Telephone : **+61 03 8687 8000**
Project : **3134598**
Order number : **----**
C-O-C number : **----**
Sampler : **PETER LIND**
Site : **Reedy Lake**
Quote number : **EN/005/15 VICTORIA (Primary work only)**
No. of samples received : **1**
No. of samples analysed : **1**

Page : 1 of 3
Laboratory : Environmental Division Melbourne
Contact : Shirley LeCornu
Address : 4 Westall Rd Springvale VIC Australia 3171
Telephone : +61-3-8549 9630
Date Samples Received : 01-Mar-2017 11:45
Date Analysis Commenced : 02-Mar-2017
Issue Date : 07-Mar-2017 12:41



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Nikki Stepniewski	Senior Inorganic Instrument Chemist	Melbourne Inorganics, Springvale, VIC



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Samples were filtered through a 0.45um filter prior to the dissolved metals analysis.
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.



Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	WQM	----	----	----	----
Client sampling date / time				28-Feb-2017 00:00	----	----	----	----	
Compound	CAS Number	LOR	Unit	EM1702319-001	-----	-----	-----	-----	
				Result	----	----	----	----	
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----	
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	----	----	----	----	
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	239	----	----	----	----	
Total Alkalinity as CaCO3	----	1	mg/L	239	----	----	----	----	
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	830	----	----	----	----	
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L	7670	----	----	----	----	
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L	217	----	----	----	----	
Magnesium	7439-95-4	1	mg/L	457	----	----	----	----	
Sodium	7440-23-5	1	mg/L	3670	----	----	----	----	
Potassium	7440-09-7	1	mg/L	120	----	----	----	----	
EG020F: Dissolved Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L	0.100	----	----	----	----	
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	----	----	----	----	
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----	
Copper	7440-50-8	0.001	mg/L	0.002	----	----	----	----	
Nickel	7440-02-0	0.001	mg/L	0.003	----	----	----	----	
Lead	7439-92-1	0.001	mg/L	<0.001	----	----	----	----	
Zinc	7440-66-6	0.005	mg/L	<0.005	----	----	----	----	
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----	
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L	238	----	----	----	----	
Total Cations	----	0.01	meq/L	211	----	----	----	----	
Ionic Balance	----	0.01	%	6.07	----	----	----	----	
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L	43	----	----	----	----	
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L	59	----	----	----	----	



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ALS Laboratory
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WOLLONGONG: 99 Kenny Street, Wollongong NSW 2500
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CLIENT: GHD
OFFICE: 400 Leichhardt Street, Sydney NSW 1589
Reedy Lake 3134598
ORDER NUMBER:
PROJECT MANAGER: Peter Lind
SAMPLER: Peter Lind
CONTACT PH: 0403 835 098
SAMPLER MOBILE: 0403 835 098
EDD FORMAT (or default):
COC emailed to ALS? (YES / NO)
Email Reports to (will default to PM if no other addresses are listed):
Email Invoice to (will default to PM if no other addresses are listed):

TURNAROUND REQUIREMENTS: Standard TAT (List due date):
(Standard TAT may be longer for some tests e.g. Ultra Trace Organics)
ALS QUOTE NO.:
RECEIVED BY: Peter Lind
RELINQUISHED BY: Peter Lind
RECEIVED BY: Peter Lind
DATE/TIME: 1/3/2017

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE codes below	TOTAL CONTAINERS (refer to)	ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).										Additional Information	
						Soil EA05P pH (PC)	Soil EA010P Conductivity (PC)	Soil ED038 CaCO3 Acidity as CaCO3 only	Soil EG020W Water leachable metals by ICPMS	Soil EG03835W Water leachable mercury by FIMS	Soil NT-01 Major cations	Soil NT-02A Major anions	Soil EG020W Water leachable metals by ICPMS	Soil EG03835W Water leachable mercury by FIMS	Soil NT-01 Major cations		Soil NT-02A Major anions
1	WQ_out	28/02/2017	Soil		2	X	X	X	X	X	X	X	X	X	X		
2	S8	28/02/2017	Soil		2	X	X	X	X	X	X	X	X	X	X		
3	S7 Dry	28/02/2017	Soil		2	X	X	X	X	X	X	X	X	X	X		
4	S7 Wet	28/02/2017	Soil		2	X	X	X	X	X	X	X	X	X	X		
5	S7 Moist	28/02/2017	Soil		2	X	X	X	X	X	X	X	X	X	X		
TOTAL																	

Environmental Division
Melbourne
Work Order Reference
EM1702327



Telephone : + 61-3-8649 9600

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl Preserved Plastic; HS = HCl Preserved Plastic; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Solids; B = Unpreserved Bag

CERTIFICATE OF ANALYSIS

Work Order	: EM1702327	Page	: 1 of 4
Client	: GHD PTY LTD	Laboratory	: Environmental Division Melbourne
Contact	: MR PETER LIND	Contact	: Shirley LeCornu
Address	: LEVEL 8, 180 LONSDALE ST MELBOURNE VIC, AUSTRALIA 3001	Address	: 4 Westall Rd Springvale VIC Australia 3171
Telephone	: +61 03 8687 8000	Telephone	: +61-3-8549 9630
Project	: 3134598	Date Samples Received	: 01-Mar-2017 11:45
Order number	: ----	Date Analysis Commenced	: 06-Mar-2017
C-O-C number	: ----	Issue Date	: 22-Mar-2017 12:46
Sampler	: ----		
Site	: Reedy Lake		
Quote number	: EN/005/15 VICTORIA (Primary work only)		
No. of samples received	: 5		
No. of samples analysed	: 5		



Accreditation No. 825
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This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Chris Lemaitre	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Eric Chau	Metals Team Leader	Melbourne Inorganics, Springvale, VIC



General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EC conducted 7/3 to meet holding time requirement.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- ED038: EM1702327-001 insufficient sample remains to analyse Acidity by PCT
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.



Analytical Results

Sub-Matrix: DI WATER LEACHATE
 (Matrix: WATER)

Client sample ID

				WQ_out	S8	S7 Dry	S7 Wet	S7 Moist
Client sampling date / time				28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00
Compound	CAS Number	LOR	Unit	EM1702327-001	EM1702327-002	EM1702327-003	EM1702327-004	EM1702327-005
				Result	Result	Result	Result	Result
EG005W: Water Leachable Metals by ICPAES								
Aluminium	7429-90-5	0.1	mg/L	<0.10	<0.10	<0.10	0.23	<0.10
Antimony	7440-36-0	0.01	mg/L	0.02	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.01	mg/L	0.05	0.03	<0.01	0.07	0.06
Cadmium	7440-43-9	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	7440-47-3	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	7439-89-6	0.05	mg/L	0.35	0.31	0.06	0.82	0.34
Lead	7439-92-1	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001



Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)		Client sample ID			WQ_out	S8	S7 Dry	S7 Wet	S7 Moist
Client sampling date / time		28-Feb-2017 00:00			28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00	28-Feb-2017 00:00
Compound	CAS Number	LOR	Unit	EM1702327-001	EM1702327-002	EM1702327-003	EM1702327-004	EM1702327-005	
				Result	Result	Result	Result	Result	
EA001: pH in soil using 0.01M CaCl extract									
pH (CaCl2)	----	0.1	pH Unit	7.6	7.3	7.3	7.5	7.3	
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm	14200	15400	12400	7240	2020	
EA055: Moisture Content									
Moisture Content (dried @ 103°C)	----	1	%	7.9	8.3	31.7	7.6	46.9	
ED038A: Acidity									
Acidity	----	1	mg/kg	28	170	17	58	8	
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg	2080	2220	5100	700	180	
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg	28000	30300	34200	13000	6000	
ED093S: Soluble Major Cations									
Calcium	7440-70-2	10	mg/kg	510	950	1890	360	120	
Magnesium	7439-95-4	10	mg/kg	1480	1510	1910	540	170	
Sodium	7440-23-5	10	mg/kg	12900	14300	14000	5950	3070	
Potassium	7440-09-7	10	mg/kg	580	580	480	320	160	
EN60: Bottle Leaching Procedure									
Final pH	----	0.1	pH Unit	8.0	8.0	7.4	8.2	8.0	



CHAIN OF CUSTODY
ALS Laboratory
please tick →

ADelaide 21 Burma Road Pterodactyl SA 5095
Ph: 08 8359 0800 E: adelaide@alsglobal.com
BRISBANE 32 Shand Street Stretford QLD 4053
Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
GLADSTONE 46 Callomonah Drive Clinton QLD 4680
Ph: 07 7471 5600 E: gladstone@alsglobal.com
MACKAY 28 Macbray Road Mackay QLD 4740
Ph: 07 4044 0177 E: mackay@alsglobal.com
MELBOURNE 2-4 Westall Road Springvale VIC 3171
Ph: 03 8549 0600 E: samples.melbourne@alsglobal.com
MILDREE 27 Sydney Road Mudgee NSW 2850
Ph: 02 8372 6735 E: mudgee.mel@alsglobal.com
NEWCASTLE 5 Rose Gum Road Warbrook NSW 2304
Ph: 02 4968 9433 E: samples.newcastle@alsglobal.com
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PERTH 10 Hod Way Malaga WA 6060
Ph: 08 9209 7555 E: samples.perth@alsglobal.com
SYDNEY 277-289 Woodpark Road Smithfield NSW 2164
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TOWNSVILLE 14-15 Deans Court Bohle QLD 4818
Ph: 07 4786 0600 E: townsville.environment@alsglobal.com
LIVOLONGONG 98 Kerry Street Wollongong NSW 2560
Ph: 02 4225 3125 E: portkembla@alsglobal.com

CLIENT: GHD
OFFICE: *Landscape Architecture*
PROJECT: 3134598 Reedy Lake
ORDER NUMBER:
PROJECT MANAGER: Peter Lind
SAMPLER: Peter Lind
COC emailed to ALS? (YES / NO)
Email Reports to (will default to PM if no other addresses are listed):
Email Invoice to (will default to PM if no other addresses are listed):

TURNAROUND REQUIREMENTS:
 Standard TAT (List due date):
 Non Standard or urgent TAT (List due date):
ALS QUOTE NO.:
CONTACT PH: 0403 835 098
SAMPLER MOBILE: 0403 835 098
EDD FORMAT (or default):

RELINQUISHED BY:
Peter Lind
DATE/TIME:
5/4/17

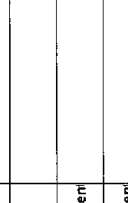
RELINQUISHED BY:
NF
DATE/TIME:
5/4/17

COC SEQUENCE NUMBER (Circle)
coc: 1 2 3 4 5 6 7
of: 1 2 3 4 5 6 7

RECEIVED BY:
NF
DATE/TIME:
5/4/17

FOR LABORATORY USE ONLY (GIG/A)
Gig/A: ()
Fresh: ()
Random Samples: ()
On-site: ()

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).

LAB ID	SAMPLE ID	DATE / TIME	MATRIX	TYPE & PRESERVATIVE codes below	TOTAL CONTAINERS (refer to codes below)	Soil EA05P pH (PC)	Soil AE010P Conductivity (PC)	Soil ED038 CaCO3 only Acidity as CaCO3	Soil EG020W Water leachable metals by ICPMS	Soil EGO3835W Water leachable mercury by FIMS	Soil NT-01 Major Cations	Soil NT-02A Major Anions	Additional Information
1	S1	4/04/2017	Sediment		2	X	X	X	X	X			Comments on likely contaminant levels, dilutions, or samples requiring specific GC analysis etc. Environmental Division Melbourne Work Order Reference EM1704190  Telephone : +61-3-9649 9800
2	S8	4/04/2017	Sediment		2	X	X	X	X	X			
3	S7 - Wet	4/04/2017	Sediment		2	X	X	X	X	X			
4	S7 - Moist	4/04/2017	Sediment		2	X	X	X	X	X			
5	S7 - Dry	4/04/2017	Sediment		2	X	X	X	X	X			
6	Dup	4/04/2017	Sediment		2	X	X	X	X	X			
					TOTAL								

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide/Cd Preserved; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sulfuric Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Plastic; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CERTIFICATE OF ANALYSIS

Work Order : **EM1704190**
Client : **GHD PTY LTD**
Contact : **MR PETER LIND**
Address : **LEVEL 8, 180 LONSDALE ST**
MELBOURNE VIC, AUSTRALIA 3001
Telephone : **+61 03 8687 8000**
Project : **3134598**
Order number : **----**
C-O-C number : **----**
Sampler : **PETER LIND**
Site : **Reedy Lake**
Quote number : **EN/005/15 VICTORIA (Primary work only)**
No. of samples received : **5**
No. of samples analysed : **5**

Page : 1 of 4
Laboratory : Environmental Division Melbourne
Contact : Shirley LeCornu
Address : 4 Westall Rd Springvale VIC Australia 3171
Telephone : +61-3-8549 9630
Date Samples Received : 05-Apr-2017 14:40
Date Analysis Commenced : 06-Apr-2017
Issue Date : 11-Apr-2017 12:43



Accreditation No. 825
 Accredited for compliance with
 ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

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<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Chris Lemaitre	Non-Metals Team Leader	Melbourne Inorganics, Springvale, VIC
Eric Chau	Metals Team Leader	Melbourne Inorganics, Springvale, VIC



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Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

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^ = This result is computed from individual analyte detections at or above the level of reporting
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~ = Indicates an estimated value.

- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- ED045G: The presence of thiocyanate can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.
- ED045G: EM1704190 #2 Poor matrix spike recovery for chloride due to matrix effects.



Analytical Results

Sub-Matrix: DI WATER LEACHATE
 (Matrix: WATER)

Client sample ID

				S1	S8	S7 - Wet	S7 - Moist	S7 - Dry
Client sampling date / time				04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00
Compound	CAS Number	LOR	Unit	EM1704190-001	EM1704190-002	EM1704190-003	EM1704190-004	EM1704190-005
				Result	Result	Result	Result	Result
EG005W: Water Leachable Metals by ICPAES								
Aluminium	7429-90-5	0.1	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10
Antimony	7440-36-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.01	mg/L	0.09	0.04	0.10	0.02	<0.01
Cadmium	7440-43-9	0.005	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	7440-47-3	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	7439-89-6	0.05	mg/L	0.09	0.51	0.29	<0.05	<0.05
Lead	7439-92-1	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	7440-02-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
EG035W: Water Leachable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001



Analytical Results

Sub-Matrix: SEDIMENT (Matrix: SOIL)		Client sample ID			S1	S8	S7 - Wet	S7 - Moist	S7 - Dry
Client sampling date / time		04-Apr-2017 00:00			04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00	04-Apr-2017 00:00
Compound	CAS Number	LOR	Unit	EM1704190-001	EM1704190-002	EM1704190-003	EM1704190-004	EM1704190-005	
				Result	Result	Result	Result	Result	
EA001: pH in soil using 0.01M CaCl extract									
pH (CaCl2)	----	0.1	pH Unit	7.3	6.9	7.5	7.6	6.6	
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm	2110	2050	2180	11500	3410	
EA055: Moisture Content									
Moisture Content (dried @ 103°C)	----	1	%	59.1	78.1	52.6	45.9	20.4	
ED037: Alkalinity									
Total Alkalinity as CaCO3	----	1	mg/kg	85	77	69	40	12	
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	85	77	69	40	12	
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<1	<1	<1	<1	<1	
ED038A: Acidity									
Acidity	----	1	mg/kg	10	11	4	8	6	
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg	820	720	1280	17100	3840	
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg	8320	15800	7880	34300	4540	
ED093S: Soluble Major Cations									
Calcium	7440-70-2	10	mg/kg	150	480	170	6490	900	
Magnesium	7439-95-4	10	mg/kg	280	640	250	3930	700	
Sodium	7440-23-5	10	mg/kg	4590	8040	4810	14600	3280	
Potassium	7440-09-7	10	mg/kg	290	440	270	370	200	
EN60: Bottle Leaching Procedure									
Final pH	----	0.1	pH Unit	7.8	7.2	8.0	7.2	7.0	

Appendix B – - Species list of birds recorded at
Reedy Lake, as presented in Mackenzie *et al.* (2006)

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
Stubble Quail	<i>Coturnix pectoralis</i>					Ma					y		
Buff-banded Rail	<i>Gallirallus philippensis</i>										y		y
Australian Spotted Crake	<i>Porzana fluminea</i>										y		y
Baillon's Crake	<i>Porzana pusilla</i>		L	VU		Ma					y		y
Spotless Crake	<i>Porzana tabuensis</i>					Ma					y		y
Black-tailed Native-hen	<i>Gallinula ventralis</i>										y		y
Dusky Moorhen	<i>Gallinula tenebrosa</i>										y		y
Purple Swamphen	<i>Porphyrio porphyrio</i>										y	y	y
Eurasian Coot	<i>Fulica atra</i>										y		y
Great Crested Grebe	<i>Podiceps cristatus</i>										y		y
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>										y		y
Hoary-headed Grebe	<i>Poliiocephalus poliocephalus</i>										y		y
Great Cormorant	<i>Phalacrocorax carbo</i>										y		y
Little Black Cormorant	<i>Phalacrocorax sulcirostris</i>										y		y
Pied Cormorant	<i>Phalacrocorax varius</i>			NT							y		y
Little Pied Cormorant	<i>Phalacrocorax melanoleucos</i>										y		y
Australasian Darter	<i>Anhinga novaehollandiae</i>										y		y
Australian Pelican	<i>Pelecanus conspicillatus</i>					Ma					y	y	y
White-winged Black Tern	<i>Chlidonias leucopterus</i>			NT	Mi	Ma	yes		yes		y		y
Whiskered Tern	<i>Chlidonias hybridus</i>			NT		Ma					y		y
Gull-billed Tern	<i>Sterna nilotica</i>		L	EN	Mi	Ma					y		y
Caspian Tern	<i>Sterna caspia</i>		L	NT	Mi	Ma					y		y
Crested Tern	<i>Sterna bergii</i>					Ma					y		y
Little Tern	<i>Sternula albigrons</i>		L	VU	Mi	Ma	yes	yes	yes	yes	y		y
Fairy Tern	<i>Sternula nereis</i>	VU	L	EN		Ma					y		y
Silver Gull	<i>Larus novaehollandiae</i>					Ma					y		y
Pacific Gull	<i>Larus pacificus</i>			NT		Ma					y		y
Masked Lapwing	<i>Vanellus miles</i>										y	y	y
Banded Lapwing	<i>Vanellus tricolor</i>										y		y
Red-kneed Dotterel	<i>Erythrogonys cinctus</i>										y		y

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
Double-banded Plover	<i>Charadrius bicinctus</i>				Mi	Ma				yes	y		y
Red-capped Plover	<i>Charadrius ruficapillus</i>					Ma					y		y
Black-fronted Dotterel	<i>Elseyaornis melanops</i>										y		y
Black-winged Stilt	<i>Himantopus himantopus</i>					Ma					y		y
Red-necked Avocet	<i>Recurvirostra novaehollandiae</i>					Ma					y		y
Black-tailed Godwit	<i>Limosa limosa</i>			VU	Mi	Ma	yes	yes	yes	yes	y		y
Wood Sandpiper	<i>Tringa glareola</i>			VU	Mi	Ma	yes	yes	yes	yes	y		y
Common Greenshank	<i>Tringa nebularia</i>			VU	Mi	Ma	yes	yes	yes	yes	y		y
Marsh Sandpiper	<i>Tringa stagnatilis</i>			VU	Mi	Ma	yes	yes	yes	yes	y		y
Curlew Sandpiper	<i>Calidris ferruginea</i>	CR		EN	Mi	Ma	yes	yes	yes	yes	y		y
Red-necked Stint	<i>Calidris ruficollis</i>				Mi	Ma	yes	yes	yes	yes	y		y
Sharp-tailed Sandpiper	<i>Calidris acuminata</i>				Mi	Ma	yes	yes	yes	yes	y		y
Red Knot	<i>Calidris canutus</i>	EN		EN	Mi	Ma	yes	yes	yes	yes	y		y
Broad-billed Sandpiper	<i>Limicola falcinellus</i>				Mi	Ma	yes	yes	yes	yes	y		y
Long-toed Stint	<i>Calidris subminuta</i>			NT	Mi	Ma	yes	yes	yes	yes	y		y
Pectoral Sandpiper	<i>Calidris melanotos</i>			NT	Mi	Ma	yes		yes	yes	y		y
Ruff	<i>Philomachus pugnax</i>				Mi	Ma	yes	yes	yes	yes	y		y
Lesser Yellowlegs	<i>Tringa flavipes</i>										y		y
Latham's Snipe	<i>Gallinago hardwickii</i>			NT	Mi	Ma	yes	yes	yes	yes	y		y
Australian Painted Snipe	<i>Rostratula australis (=benghalensis)</i>	EN	L	CR		Ma					y		y
Brolga	<i>Grus rubicunda</i>		L	VU							y		y
Glossy Ibis	<i>Plegadis falcinellus</i>			NT	Mi	Ma		yes		yes	y		y
Australian White Ibis	<i>Threskiornis molucca</i>					Ma					y	y	y
Straw-necked Ibis	<i>Threskiornis spinicollis</i>					Ma					y		y
Royal Spoonbill	<i>Platalea regia</i>			NT							y	y	y
Yellow-billed Spoonbill	<i>Platalea flavipes</i>										y	y	y
Little Egret	<i>Egretta garzetta</i>		L	EN		Ma					y		y
Intermediate Egret	<i>Ardea intermedia</i>		L	EN		Ma					y		y
Eastern Great Egret	<i>Ardea modesta (=alba)</i>		L	VU	Mi	Ma	yes	yes			y		y

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
Cattle Egret	<i>Ardea ibis</i>				Mi	Ma					y		y
White-faced Heron	<i>Egretta novaehollandiae</i>										y	y	y
White-necked Heron	<i>Ardea pacifica</i>										y		y
Nankeen Night Heron	<i>Nycticorax caledonicus</i>			NT		Ma					y		y
Little Bittern	<i>Ixobrychus minutus</i>		L	EN							y		y
Australasian Bittern	<i>Botaurus poiciloptilus</i>	EN	L	EN							y		y
Cape Barren Goose	<i>Cereopsis novaehollandiae</i>					Ma					y		y
Magpie Goose	<i>Anseranas semipalmata</i>		L	NT		Ma					y		y
Australian Wood Duck	<i>Chenonetta jubata</i>										y		y
Black Swan	<i>Cygnus atratus</i>										y		y
Australian Shelduck	<i>Tadorna tadornoides</i>										y	y	y
Pacific Black Duck	<i>Anas superciliosa</i>										y		y
Chestnut Teal	<i>Anas castanea</i>										y		y
Grey Teal	<i>Anas gracilis</i>										y		y
Australasian Shoveler	<i>Anas rhynchotis</i>			VU							y		y
Pink-eared Duck	<i>Malacorhynchus membranaceus</i>										y		y
Freckled Duck	<i>Stictonetta naevosa</i>		L	EN							y		y
Hardhead	<i>Aythya australis</i>			VU							y		y
Blue-billed Duck	<i>Oxyura australis</i>		L	EN							y		y
Musk Duck	<i>Biziura lobata</i>			VU		Ma					y		y
Spotted Harrier	<i>Circus assimilis</i>			NT							y		
Swamp Harrier	<i>Circus approximans</i>					Ma					y	y	y
Brown Goshawk	<i>Accipiter fasciatus</i>					Ma					y		
Wedge-tailed Eagle	<i>Aquila audax</i>										y		
Little Eagle	<i>Hieraaetus morphnoides</i>										y		
White-bellied Sea-eagle	<i>Haliaeetus leucogaster</i>		L	VU		Ma		yes			y		y
Whistling Kite	<i>Haliastur sphenurus</i>					Ma					y	y	y
Black-shouldered Kite	<i>Elanus axillaris</i>										y		
Australian Hobby	<i>Falco longipennis</i>										y		

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
Peregrine Falcon	<i>Falco peregrinus</i>										y		
Black Falcon	<i>Falco subniger</i>			VU							y		
Brown Falcon	<i>Falco berigora</i>										y	y	
Nankeen Kestrel	<i>Falco cenchroides</i>					Ma					y		
Pacific Barn Owl	<i>Tyto javanica (=alba)</i>										y		
Yellow-tailed Black-cockatoo	<i>Calyptorhynchus funereus</i>										y		
Little Corella	<i>Cacatua sanguinea</i>										y		
Galah	<i>Cacatua (Eolophus) roseicapilla</i>										y	y	
Cockatiel	<i>Nymphicus hollandicus</i>										y		
Crimson Rosella	<i>Platycercus elegans</i>										y		
Eastern Rosella	<i>Platycercus eximius</i>										y	y	
Red-rumped Parrot	<i>Psephotus haematonotus</i>										y	y	
Orange-bellied Parrot	<i>Neophema chrysogaster</i>	CR	L	CR		Ma					y		y
Blue-winged Parrot	<i>Neophema chrysostoma</i>					Ma					y		
Fork-tailed Swift	<i>Apus pacificus</i>				Mi	Ma	yes	yes	yes		y		
Pallid Cuckoo	<i>Cuculus pallidus</i>					Ma					y		
Fan-tailed Cuckoo	<i>Cacomantis flabelliformis</i>					Ma					y		
Horsfield's Bronze-cuckoo	<i>Chrysococcyx basalis</i>					Ma					y		
Welcome Swallow	<i>Hirundo neoxena</i>										y	y	
Tree Martin	<i>Hirundo nigricans</i>					Ma					y		
Fairy Martin	<i>Hirundo ariel</i>										y		
Grey Fantail	<i>Rhipidura fuliginosa</i>										y		
Willie Wagtail	<i>Rhipidura leucophrys</i>										y	y	
Rufous Whistler	<i>Pachycephala rufiventris</i>										y		
Grey Shrike-thrush	<i>Colluricincla harmonica</i>										y		
Magpie-lark	<i>Grallina cyanoleuca</i>										y	y	
Black-faced Cuckoo-shrike	<i>Coracina novaehollandiae</i>					Ma					y	y	
White-fronted Chat	<i>Epthianura albifrons</i>										y	y	y
Crimson Chat	<i>Epthianura tricolor</i>										y		

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
Yellow Thornbill	<i>Acanthiza nana</i>											y	
Brown Thornbill	<i>Acanthiza pusilla</i>											y	
Yellow-rumped Thornbill	<i>Acanthiza chrysorrhoa</i>										y	y	
White-browed Scrubwren	<i>Sericornis frontalis</i>										y	y	
Striated Fieldwren	<i>Calamanthus fuliginosus</i>										y	y	y
Brown Songlark	<i>Cincloramphus cruralis</i>										y		
Little Grassbird	<i>Megalurus gramineus</i>										y	y	y
Clamorous Reed Warbler	<i>Acrocephalus stentoreus</i>				Mi	Ma				yes	y	y	y
Golden-headed Cisticola	<i>Cisticola exilis</i>										y	y	y
Superb Fairy-wren	<i>Malurus cyaneus</i>										y	y	
Spotted Pardalote	<i>Pardalotus punctatus</i>										y		
Silvereye	<i>Zosterops lateralis</i>					Ma					y		
Eastern Spinebill	<i>Acanthorhynchus tenuirostris</i>										y		
Yellow-faced Honeyeater	<i>Lichenostomus chrysops</i>										y		
White-plumed Honeyeater	<i>Lichenostomus penicillatus</i>										y	y	
New Holland Honeyeater	<i>Phylidonyris novaehollandiae</i>										y	y	
Noisy Miner	<i>Manorina melanocephala</i>											y	
Red Wattlebird	<i>Anthochaera carunculata</i>										y	y	
Spiny-cheeked Honeyeater	<i>Acanthagenys rufogularis</i>										y		
Australasian Pipit	<i>Anthus novaeseelandiae</i>					Ma					y		
Horsfield's Bushlark	<i>Mirafra javanica</i>										y		
Red-browed Finch	<i>Neochmia temporalis</i>										y	y	
Little Raven	<i>Corvus mellori</i>					Ma					y	y	
Grey Butcherbird	<i>Cracticus torquatus</i>										y	y	
Australian Magpie	<i>Gymnorhina tibicen</i>										y	y	
European Skylark**	<i>Alauda arvensis</i>										y	y	
Domestic Goose**	<i>Anser anser (domestic)</i>										y		y
Rock Dove**	<i>Columba livia</i>										y		
Spotted Turtle-Dove**	<i>Streptopelia chinensis</i>										y	y	

Common Name	Scientific Name	EPBC	FFG	VICADV	EPBC Migratory	EPBC Marine	JAMBA	CAMBA	ROKAMBA	Bonn	recorded at Reedy?	recorded 21 Jan?	wetland association?
European Goldfinch**	<i>Carduelis carduelis</i>										y	y	
European Greenfinch**	<i>Carduelis chloris</i>										y		
Common Blackbird**	<i>Turdus merula</i>										y		
House Sparrow**	<i>Passer domesticus</i>										y	y	
Common Starling**	<i>Sturnus vulgaris</i>										y	y	

** denotes non-native species

Appendix C – Plant Functional Group Definitions

Source: Casanova (2011). *, introduced species.

Tdr Terrestrial dry. This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands, but are essentially terrestrial.

Examples: *Senecio pinnatifolius* (Variable Groundsel), **Phalaris aquatica* (Toowoomba Canary-grass).

Tda Terrestrial damp. These species germinate and establish on saturated or damp ground, but cannot tolerate flooding in the vegetative state. As such, they can persist throughout the environment in dry puddles and drains. They grow on bare ground following flooding or in places where floodwater has spread out over the landscape long enough to saturate the soil profile. They require the soil profile to remain damp for around three months.

Examples: *Juncus procerus* (Tall Rush), **Atriplex prostrata* (Creeping Saltbush).

ATI Amphibious fluctuation tolerator – low-growing. This species group can germinate either on saturated soil or under water and grow totally submerged, as long as they are exposed to air by the time they start to flower and set seed. They require shallow flooding for around three months.

Examples: *Lilaeopsis polyantha* (Australian Lilaeopsis), *Thyridia repens* (Creeping Monkey-flower).

ATe Amphibious fluctuation tolerator – emergent. This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water to be present for 8–10 months of the year, and the dry time to be in the cooler times of the year.

Examples: *Phragmites australis* (Common Reed), *Sarcocornia quinqueflora* (Beaded Glasswort), *Eleocharis acuta* (Common Spike-rush), **Paspalum distichum* (Water Couch).

ATw Amphibious fluctuation tolerator – woody. This species group consists of woody perennial species that hold their seeds on their branches and require water to be present in the root zone all year round, but will germinate in shallow water or on a drying profile. If they grow on floodplains, they require flooding and restoration of groundwater levels on a regular basis.

Example: *Duma florulenta* (Lignum).

ARp Amphibious fluctuation responder– plastic. This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf type. They can persist on damp and drying ground because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper /wet-for-longer site than the ATI group.

Examples: *Crassula helmsii* (Swamp Crassula), **Cotula coronopifolia* (Water Buttons).

ARf Amphibious fluctuation responder– floating. This group consists of species that grow underwater or float on the surface of the water or have floating leaves. They require the year-round presence of free water. Many of these can survive and complete their life cycle stranded on the mud, but they reach maximum biomass growing in 'open' water all year round.

Examples: *Ornduffia reniformis* (Running Marsh-flower), *Ranunculus amphitrichus* (Small River Buttercup).

Se Perennial – emergent. This category refers to woody and monocotyledonous species that require permanent water in the root zone, but remain emergent. They thrive where water levels do not fluctuate or fluctuate little (i.e. weir pools, dams).

Examples: *Typha orientalis* (Broad-leaf Cumbungi), *Bolboschoenus caldwellii* (Salt Club-rush).

Sk Submerged – k-selected. These species require a site be flooded to >10 cm for at least six months for them to either germinate or reach sufficient biomass to start reproducing sexually. Many have asexual reproduction (fragmentation, rhizomes and turions). Completely water-dependent, true aquatic species.

Examples: *Stuckenia pectinata* (Fennel Pondweed), *Chara* sp. (algae).

Sr Submerged – r-selected. These species colonise recently flooded areas. Many require drying to stimulate high germination percentages, and they frequently complete their life cycle quickly and die off naturally. They persist via a dormant, long-lived bank of seeds or spores in the soil. Their habitats can be flooded from once a year to once a decade, to a depth >10 cm.

Example: *Lepilaena cylindrocarpa* (Long-fruit Water-mat).

Species recorded in 2010 and 2016 (24 quadrats), structural group (native species), Plant Functional Groups (PFGs) and water depth.

*, introduced species.

Plant Functional Groups are taken from Casanova (2015).

Species	Structural group	PFG	Water depth range 2010 and 2016 (cm)
* <i>Atriplex prostrata</i>	SHG	Tda Terrestrial damp	0
<i>Azolla rubra</i>	SHG	ARf Amphibious fluctuation responder– floating	50-80
<i>Bolboschoenus caldwellii</i>	MG	Se Perennial – emergent	0-60
<i>Calystegia sepium</i>	SHG	Tdr Terrestrial dry	0-30
* <i>Carduus tenuiflorus</i>		Tda Terrestrial damp	10
<i>Chara</i> sp.	SHG	Sk Submerged – k-selected	15-60
* <i>Cirsium vulgare</i>		Tdr Terrestrial dry	0-5
* <i>Cotula coronopifolia</i>		ARp Amphibious fluctuation responder– plastic	0-40
<i>Crassula helmsii</i>	SHG	ARp Amphibious fluctuation responder– plastic	0-70
<i>Distichlis distichophylla</i>	SHG	Tda Terrestrial damp	0-5
<i>Duma florulenta</i>	WP	ATw Amphibious fluctuation tolerator – woody	0-10
<i>Eleocharis acuta</i>	SHG	ATe Amphibious fluctuation tolerator – emergent	0-60
<i>Eleocharis sphacelata</i>	MG	ATe Amphibious fluctuation tolerator – emergent	0-30
<i>Epilobium billardierianum</i>	SHG	Tda Terrestrial damp	0
* <i>Erigeron sumatrensis</i>		Tda Terrestrial damp	0
<i>Frankenia pauciflora</i> var. <i>gunnii</i>	WP	Tda Terrestrial damp	0-5
* <i>Hordeum marinum</i>		Tdr Terrestrial dry	0-10
<i>Hydrocotyle</i> sp.	SHG	ATI Amphibious fluctuation tolerator – low-growing	5
<i>Isolepis cernua</i>	SHG	ATI Amphibious fluctuation tolerator – low-growing	0-10
<i>Juncus procerus</i>	MG	Tda Terrestrial damp	5-60
<i>Juncus</i> sp.	SHG	Tda Terrestrial damp	5
<i>Lachnagrostis filiformis</i>	SHG	ATe Amphibious fluctuation tolerator – emergent	0-5
<i>Lemna disperma</i>	SHG	ARf Amphibious fluctuation responder– floating	5-60
<i>Lemna trisulca</i>	SHG	ARf Amphibious fluctuation responder– floating	15
<i>Lepilaena cylindrocarpa</i>	SHG	Sr submerged - r - selected	40-60
<i>Lilaeopsis polyantha</i>	SHG	ATI Amphibious fluctuation tolerator – low-growing	50
* <i>Lolium hybridum</i>		Tdr Terrestrial dry.	0
* <i>Lolium multiflorum</i> x <i>rigidum</i>		Tdr Terrestrial dry	0
<i>Lycopus australis</i>	SHG	ATe Amphibious fluctuation tolerator – emergent	12

Species	Structural group	PFG	Water depth range 2010 and 2016 (cm)
<i>Lythrum hyssopifolia</i>	SHG	Tda Terrestrial damp	0
<i>Melaleuca brevifolia</i>	WP	Tdr Terrestrial dry	
<i>Myriophyllum salsugineum</i>	SHG	ARp Amphibious fluctuation responder– plastic	5-60
<i>Ornduffia reniformis</i>	SHG	ARf Amphibious fluctuation responder– floating	40-60
* <i>Paspalum distichum</i>		ATe Amphibious fluctuation tolerator – emergent	20-60
* <i>Phalaris aquatica</i>		Tdr Terrestrial dry	0
<i>Phragmites australis</i>	DR	ATe Amphibious fluctuation tolerator – emergent	0-50
<i>Poaceae sp.</i>	SHG	Tda Terrestrial damp	0-10
<i>Poa poiformis var. poiformis</i>	MG	Tda Terrestrial damp	0-10
* <i>Polypogon monspeliensis</i>		ATe Amphibious fluctuation tolerator – emergent	0-10
<i>Potamogeton crispus</i>	SHG	ARp Amphibious fluctuation responder– plastic	5-15
<i>Potamogeton sp.</i>	SHG	ARp Amphibious fluctuation responder– plastic	15
<i>Ranunculus amphitrichus</i>	SHG	ARf Amphibious fluctuation responder– floating	0-60
<i>Rumex bidens</i>	SHG	ARp Amphibious fluctuation responder– plastic	60
* <i>Rumex conglomeratus</i>		Tda Terrestrial damp	0-60
* <i>Rumex crispus</i>		Tda Terrestrial damp	0-12
<i>Sarcocornia quinqueflora</i>	SHG	ATe Amphibious fluctuation tolerator – emergent	0-10
<i>Schoenoplectus tabernaemontani</i>	MG	Se Perennial – emergent	50
<i>Selliera radicans</i>	SHG	ATI Amphibious fluctuation tolerator – low-growing	30-40
<i>Senecio pinnatifolius</i>	SHG	Tdr Terrestrial dry	0-40
* <i>Sonchus oleraceus</i>		Tdr Terrestrial dry	0
<i>Spergularia tasmanica</i>	SHG	ATI Amphibious fluctuation tolerator – low-growing	10
<i>Stuckenia pectinata</i>	SHG	Sk Submerged – k-selected	5-60
* <i>Symphyotrichum subulatum</i>		Tda Terrestrial damp	
<i>Tecticornia pergranulata</i>	WP	ATe Amphibious fluctuation tolerator – emergent	0-10
<i>Thyridia repens</i>	SHG	ATI Amphibious fluctuation tolerator – low-growing	5-15
<i>Triglochin procerum</i>	SHG	Se Perennial – emergent	0-40
<i>Triglochin striatum</i>	SHG	ATe Amphibious fluctuation tolerator – emergent	0-10
<i>Typha orientalis</i>	DR	Se Perennial – emergent	0-80

Mapping

Vegetation mapping classes generated by Ecological Associates (2012) were revised to align with Victorian Ecological Vegetation Classes and EPBC Act Ecological communities, with reference to Sinclair (2010).

Table. Ecological Vegetation Classes (EVCs), Reedy Lake (Sinclair 2010). Comparison with earlier vegetation mapping of Yugovic (1985) and Ecological Associates (2012).

now *Duma florulenta*

Sinclair (2010) Ecological Vegetation Classes	EVC number	EPBC Act listed ecological community	Yugovic (1985) vegetation communities	Ecological Associates (2012) vegetation communities
Seasonally Inundated Sub-saline Herbland	EVC 196		1. <i>Wilsonia humilis</i> Herbland	10 <i>Wilsonia humilis</i> herbland
Mangrove Shrubland	EVC 140		2. <i>Avicennia marina</i> Shrubland	Not present the study area

Sinclair (2010) Ecological Vegetation Classes	EVC number	EPBC Act listed ecological community	Yugovic (1985) vegetation communities	Ecological Associates (2012) vegetation communities
Estuarine Wetland	EVC 10	Subtropical and temperate coastal saltmarsh	3. Juncus kraussii Rushland	12 Juncus kraussii Rushland
Wet Saltmarsh Herbland	EVC A107	Subtropical and temperate coastal saltmarsh	4. Samphire Herbfield Complex	4.1 Sarcocornia quinqueflora Herbfield
Coastal Hypersaline Saltmarsh	A111	Subtropical and temperate coastal saltmarsh	5. Samphire Shrubland Complex	4.2 Tecticornia pergranulata Shrubland
Coastal Hypersaline Saltmarsh	A111			4.3 Halosarcia halocnemoides Shrubland
Wet Saltmarsh Shrubland	A108			4.4 Sclerostegia arbuscula Shrubland
Coastal Tussock Saltmarsh	A112		6. Gahnia filum Sedgeland	1.1 Gahnia filum Sedgeland 1.2 Juvenile Gahnia filum with Poa poiformis
Estuarine Flats Grassland	914		7. Poa poiformis Grassland	7. Poa labillardierei Grassland
Coastal Saline Grassland	A109		8. Distichlis distichophylla Grassland / Shrubland	11 Distichlis distichophylla Grassland
Brackish Lignum Swamp	947		9. #Muehlenbeckia cunninghamii Shrubland	3.1 #Muehlenbeckia florulenta Shrubland over Native Herbs 3.2 #Muehlenbeckia florulenta Shrubland over Distichlis distichophylla 3.3 #Muehlenbeckia florulenta Shrubland over Exotic Grasses
Not observed			10. Eleocharis acuta Sedgeland	Not observed
Brackish Wetland Aggregate	656		11. Schoenoplectus pungens Sedgeland	9.1 Bolboschoenus caldwellii Sedgeland 9.2 Bolboschoenus caldwellii Sedgeland with Distichlis distichophylla

Sinclair (2010) Ecological Vegetation Classes	EVC number	EPBC Act listed ecological community	Yugovic (1985) vegetation communities	Ecological Associates (2012) vegetation communities
Tall Marsh	821		12. Phragmites australis Grassland Complex	8 Phragmites australis and Typha orientalis Grassland
Coastal Alkaline Scrub	858		13. Melaleuca lanceolata Scrub	Not present the study area
			14. Exotic Vegetation	13.1 Exotic Pasture Grasses and Weeds 13.2 Planted Vegetation 13.3 Planted Red Gum
Saline Aquatic Meadow	842		Bare areas	5.1 Open water with Ruppia polycarpa and Lepilaena cylindrocarpa 5.2 Open water with areas of Myriophyllum salsugineum and M. verrucosum 5.3 Bolboschoenus caldwellii marsh 5.4 Schoenoplectus validus Sedgeland 5.5 Juncus procerus Rushland
Included in Tall Marsh	821			
Included in Tall Marsh	821			
Included in Tall Marsh	821			
Included in Tall Marsh	821			
Berm Grassy Shrubland	311		Not mapped	2 Stipa stipoides Grassland
Included in Tall Marsh	821		Not mapped	6 Villarsia reniformis Marshland

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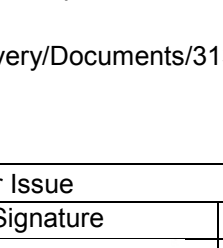


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